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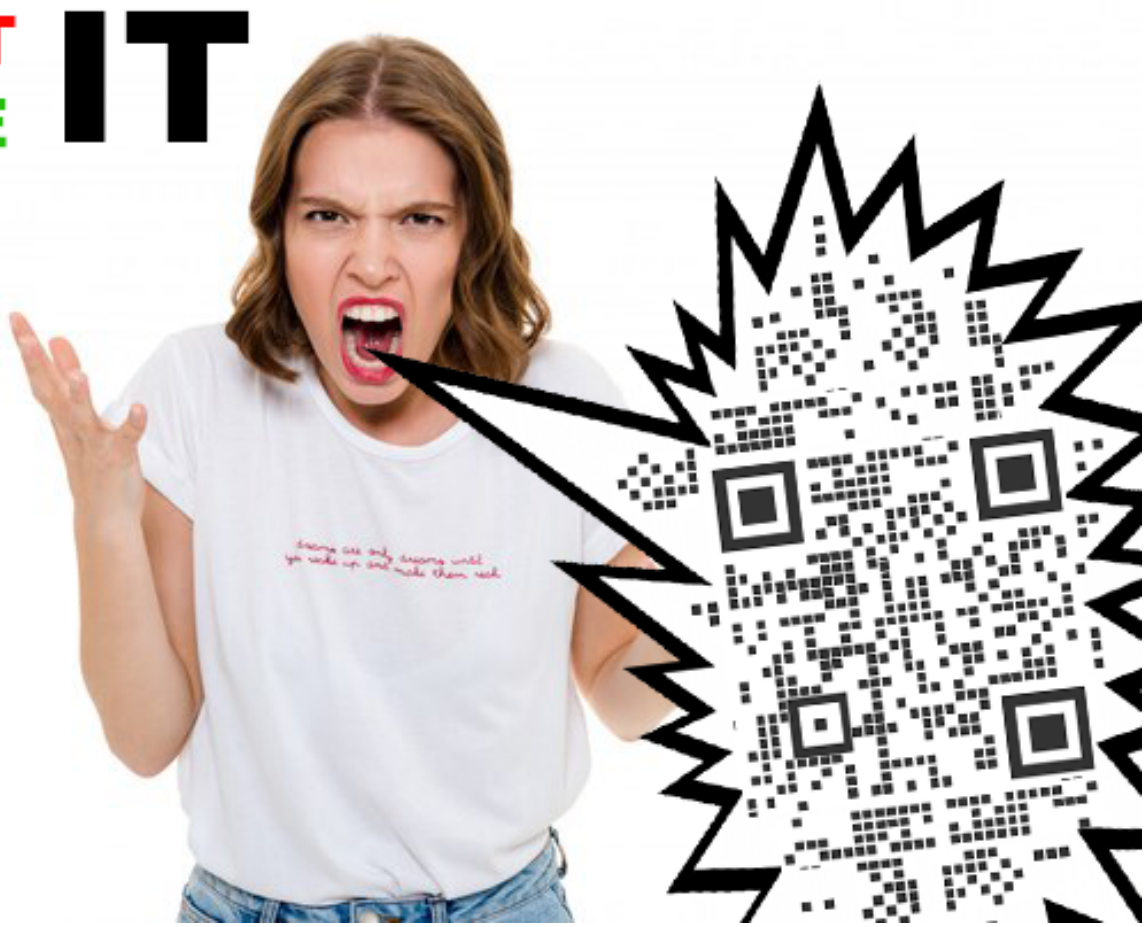

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U. S. DEPARTMENT OF AGRICULTURE,
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L. O. HOWARD, Entomologist and Chief of Bureau.

THE SAN JOSE OR CHINESE SCALE.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., August 31, 1906.

Sir: I have the honor to submit for publication a manuscript entitled "The San Jose or Chinese Scale," which is a thoro revision of the previous publications on this subject issued by the Department, namely, Bulletins Nos. 3 and 12, new series, of this office. In spite of the large number of articles which have been published concerning this insect in experiment station bulletins and in journals and magazines, there is a distinct need for a comprehensive treatment of this most important subject, and this need, I think, has been met in an excellent way by Mr. Marlatt in this manuscript. I recommend that it be published as Bulletin No. 62 of this Bureau.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

Bulletin No. 3 (new series) of this office, giving a full account of the San Jose scale, was presented for publication, under the joint authorship of Doctor Howard and the writer, November 29, 1895, and included the results of two years of very thoro study of the San Jose scale. Two years later Doctor Howard issued, as Bulletin No. 12 (new series), a record of the work to the end of 1897, more particularly giving an account of the spread of the San Jose scale in the United States during the intervening period and the results of remedial work by this office and the different experiment stations, together with additions to the bibliography. It has now been more than ten years since the publication of the larger bulletin giving the full life history of this scale pest, and it seems advisable to issue a new general publication to include in one bulletin the considerable additions which have been made to our information on the subject.

The portion of Bulletin 3 giving the life history of the insect was worked out with great minuteness and is reproduced with little change. The facts relating to the original home of the insect, as discovered by the writer in 1901 in the course of explorations in China and Japan, are incorporated in this bulletin, and the distribution of the insect has been brought down to date.

The literature of the last ten years relating to the San Jose scale is of enormous volume, probably exceeding that relating to any other insect pest. Most of this literature relates, however, to the strictly economic phase of the subject—namely, distribution, injury to plants, and the means of control—together with legal enactments of various foreign countries and of the several States of the Union. The listing of all the publications on the San Jose scale subsequent to its appearance in the East in 1893 would make a bulletin of itself and would probably serve no very useful purpose, and therefore no bibliography is given in this publication. The earlier writings on this insect are, however, recorded in Bulletins 3 and 12.

The early experimental work with remedies given in Bulletin 3 is omitted, and no effort has been made to summarize the enormous body of reports on work with remedies recorded in the publications of different experiment stations in this country. The results of the later work with remedies conducted by this Bureau are to be found

in the five different editions of Circular 42, relating to the control of the San Jose scale, and in the two editions of Circular 52, relating to the lime, sulfur, and salt wash, and also in several articles in the miscellaneous bulletins of the Bureau.

Inasmuch as a good deal of the present bulletin has been rewritten, and as most of the added matter is from articles published by the writer, at the suggestion of Doctor Howard this publication is issued as a new bulletin of the Bureau series and under single authorship. Considerable matter, however, from Bulletin 3, notably that relating to life history and habits, has been used, as already indicated, with little change; this publication is largely, therefore, a compilation, with the aim of bringing the subject down to date and making it complete and available as a means of present information on the habits and status of this important scale insect pest.

The portion on true parasites (pp. 58–62) was kindly prepared by Doctor Howard, who has long been the authority on this group of parasitic four-winged flies.

C. L. M.

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THE SAN JOSE OR CHINESE SCALE.

INTRODUCTION.

The San Jose scale is now known to be of Chinese origin. Its name is derived from its first point of colonization in America, namely, at San Jose, Cal., and is, in a sense, undesirable, as giving an unmerited notoriety to the district in California which had the misfortune of being the accidental place to first harbor it. A more appropriate designation is the *Chinese scale*, but it is improbable that a new name will ever be adopted for an insect which has become so thoroly well known and exploited under its original designation.

Probably no other insect has had so much notoriety as has this species, and certainly none has assumed so great an international importance, as indicated by the vast amount of interstate and foreign legislation which has been enacted relative to it. In all the earlier publications of this office, beginning with Comstock's original description and note in the Report of the Department of Agriculture for 1880, the very great economic importance and capacity for harm of this scale insect has been commented upon and the fact that there is perhaps no insect capable of causing greater damage to fruit interests in the United States than the San Jose or pernicious scale.

It is inconspicuous and often for a time passes unnoticed or unrecognized. Meanwhile its enormous fecundity enables it to overspread the trunk, limbs, foliage, and fruit of the tree attacked (Pls. I, VI), so that it is only a question of two or three years, unless proper remedial steps be taken, before the condition of the plant becomes hopeless or its death is brought about. In capacity for harm this species probably exceeds any other scale insect known, and it attacks practically all deciduous plants, both those grown for fruit and the ornamentals. Its economic importance is further increased by the ease with which it is distributed over wide districts thru the agency of nursery stock, and the difficulty and, as a rule, impossibility of exterminating it where once introduced. Its capacity for evil, which was recognized in its earlier work on the Pacific coast, was at once even more strikingly demonstrated on its first appearance in the East, and before measures of control were undertaken it was much more disastrous in peach orchards of Maryland, New Jersey, and other eastern and southern States than in California and the West.

PRESENT STATUS OF THE PROBLEM.

The estimates given in our early publications of the seriousness of this pest have been more than borne out by the experience of the last ten years. Since its appearance on the Atlantic seaboard in the early nineties it has, in spite of all efforts at control in nurseries and by State quarantine, spread well over the eastern and middle United States and into Canada, so that there are now very few regions where fruit growing is at all important in which it has not gained permanent foothold. Maine and a few of the middle western States have not so far reported this scale insect, but it is only a question of time when it will complete its extension over the entire fruit-growing areas of North America within its climatic range.

Nevertheless the San Jose scale has not been an unmitigated scourge, and the active investigations by the Bureau of Entomology of the United States Department of Agriculture and the entomologists of the State experiment stations have demonstrated the practicability of several means of control, and particularly of the lime-sulfur wash; so that the fears aroused by this scale insect are rapidly subsiding and it no longer is considered as an insurmountable obstacle to the growth of deciduous fruits. In the case of certain fruits, as, for example, the peach, it has been found that the lime-sulfur wash has a very great value as a fungicide, and so much so that some growers are recommending its use whether the San Jose scale be present in the orchard or not. Furthermore, the presence of this scale has led to much more careful methods on the part of nurserymen and in the planting and care of stock, thus raising the standard and giving the intelligent and conscientious, painstaking grower a distinct advantage over his careless neighbor. The results in the East, in other words, are following rather closely on the experience in California and elsewhere on the Pacific coast, where the San Jose scale, long looked upon as the worst menace of the deciduous-fruit interests, is now not necessarily so regarded, and the same benefits have come to California fruit growing by the use of better methods of planting, pruning, and care.

This does not mean that the San Jose scale is to be lookt upon as a blessing. The benefits of spraying are not always uniform, and are less perhaps in the case of the apple than they are with the peach, pear, and the smoother barked fruit trees. The necessity of annual spraying of the trees is now clearly shown, and this amounts to a very large annual cost, partly offset, as already indicated, by the fungicidal value of the standard lime-sulfur application. Nevertheless, neither the injuries from the scale nor the cost of treatment have put more than a temporary check upon the advance of the fruit industry, and great confidence is being exprest by the larger commercial growers who follow out the remedies with greatest thoroness and in the most

THE SAN JOSE SCALE AND ITS WORK.

Fig. 1.—Peach tree with top killed by the scale. Fig. 2.—Peach twig, moderately infested, showing male and female scale. Fig. 3.—Peach limb badly infested with scale. Fig. 2, enlarged 4 times; fig. 3, enlarged twice. (From Quaintance.)

practical manner, and who consequently get the best results. It is now largely a matter of getting the owners of small orchards to follow a regular annual system of spraying their trees.

The presence of San Jose scale has not only resulted in a considerable increase of information as to remedies and to improvements in the methods of culture which directly relate to itself, but it has been a stimulus to improved methods and more efficient means of control of other common destructive insects, has demonstrated the necessity of watchfulness against the introduction of similar pests from foreign sources, and has led to active efforts in the direction of quarantine and inspection on the part of practically all of the several States of the Union.

The control of the San Jose scale by parasitic and predaceous enemies is increasing all the time, but there seems to be no likelihood that either such natural enemies as are now in this country or those which may hereafter be imported will ever do more than merely lessen the abundance of the scale. In other words, from past experience and from a large acquaintance with other similar scale pests it is extremely improbable that even under the most favorable circumstances will such natural enemies reduce this scale as much as would one thoro treatment with the lime-sulfur wash or other standard remedy. The insect enemy of the scale can only exist when it has scale food; hence a normal balance is very soon reached in which the scale and natural enemy fluctuate in relative abundance. A complete extermination of the scale insect or host will rarely if ever be accomplished, and there will probably always be enough scale present to cause spotted and unmarketable fruit. This does not mean that such enemies are not going to be helpful. They will decrease the virulence and destructiveness of the scale, but to get clean fruit it will probably be always necessary to spray. A very few scale on a tree will cause spotted fruit even when they may not be abundant enough to do the tree itself material injury. The fact that a large, succulent scale insect like the fluted scale of California has been controlled by a ladybird enemy does not necessarily allow one to hope for the same result with the San Jose scale. The ladybird and other enemies introduced into California to control scales similar to the San Jose scale have not succeeded in the same measure at all. This statement is made to correct hopes which may be aroused by certain popular articles which have recently appeared on the subject of parasites.

In brief, therefore, the San Jose scale must be recognized as a permanent condition to be met in the growth of deciduous fruits. The greatest care should always be taken in the purchase of nursery stock to see that it is absolutely free from infestation, and preferably also that it carries with it a certificate of fumigation. Orchards should be sprayed according to well-established methods annually as soon as the

first sign of infestation is found. Fruit growers and others interested have come to accept this conclusion and are facing the San Jose scale problem as one to be regularly dealt with, as with other established insect enemies of fruits. The range of food plants of this scale is so great that local extermination is out of the question, and it is recognized as useless to destroy orchards or new stock because of slight infestation. The San Jose scale will have so soon gained foothold on many ornamental and wild plants that such destruction of orchards would be of no avail, and new stock would be very quickly reinfested from near-by sources.

ORIGIN OF THE INSECT.

The San Jose scale was first established in this country in the early seventies at San Jose, Cal., in the grounds of Mr. James Lick.

Following the studies of Professor Comstock of this pest in California in 1880, efforts have been made to determine whence the original infestation came; in other words, to locate the native home of this insect. The importance of discovering the origin of this scale arises from the now well-known fact that where an insect is native it is normally kept in check and prevented from assuming any very destructive features, or at least maintaining such conditions over a very long time, by natural enemies, either parasitic or predaceous insects or fungous or other diseases. Mr. Lick, in whose orchard the scale first appeared, was a great lover of plants, and imported trees and shrubs for the ornamentation of his grounds from foreign countries, and it was very naturally inferred that in some of these importations he had introduced this insect. Before this investigation started, however, Mr. Lick had died, and it was impossible to trace his importations. That the scale was not European in origin was evident; otherwise it would undoubtedly have come to this country long before with the numerous importations of stock from Europe. Its original home was therefore naturally placed in some eastern country. In the course of the investigation it was found that the San Jose scale occurred in the Hawaiian Islands, in Chile, in Japan, and in Australia.[a] In the case of the Hawaiian Islands it was conclusively shown, however, that it had been carried there on stock from California. The evidence relating to Chile and Australia was of a similar nature—namely, that it had come to those countries comparatively recently on imported stock. Its occurrence in Japan was not discovered until 1897, and the evidence was far from being conclusive that it was indigenous in that country; nevertheless the belief that Japan was the source of this scale came to be rather generally accepted. The objections to it were voiced by Doctor Howard and the writer in an article read before the Association of

[a] See Bul. No. 3, new series, Div. Ent., U. S. Dept. Agric., pp. 10–12, 1896.

Economic Entomologists in 1899,[a] showing that at best the evidence left the question open. That this scale insect probably had its original home in China or Japan seemed, however, to be pretty conclusively indicated by the process of exclusion of other countries. Mr. Koebele's investigations of the Asiatic tropical regions and Australia and New Zealand had been fairly thoro, yet without finding it on native plants, and, furthermore, it was not known to occur in South Africa. The evidence pointing toward Japan and China was further emphasized by the fact that the San Jose scale is, by its relationship and distribution, an insect of the temperate regions rather than of the Tropics.

EXPLORATIONS IN EASTERN ASIA.

With the hope of settling the disputed point of the origin of the San Jose scale, and, if the native home of the species were discovered, to study, collect, and import beneficial insects to control this pest in America, the writer, in 1901–2, made a trip of exploration in Japan, China, and other Eastern countries, lasting over a year. The accompanying map (Pl. II) illustrates the regions explored. Six months were devoted to a very thoro exploration of the different islands of the Japanese Empire, and three months to China, with shorter periods in other regions. The explorations in China and Japan are the only ones which bear especially on the San Jose scale problem.

EXPLORATIONS IN JAPAN.

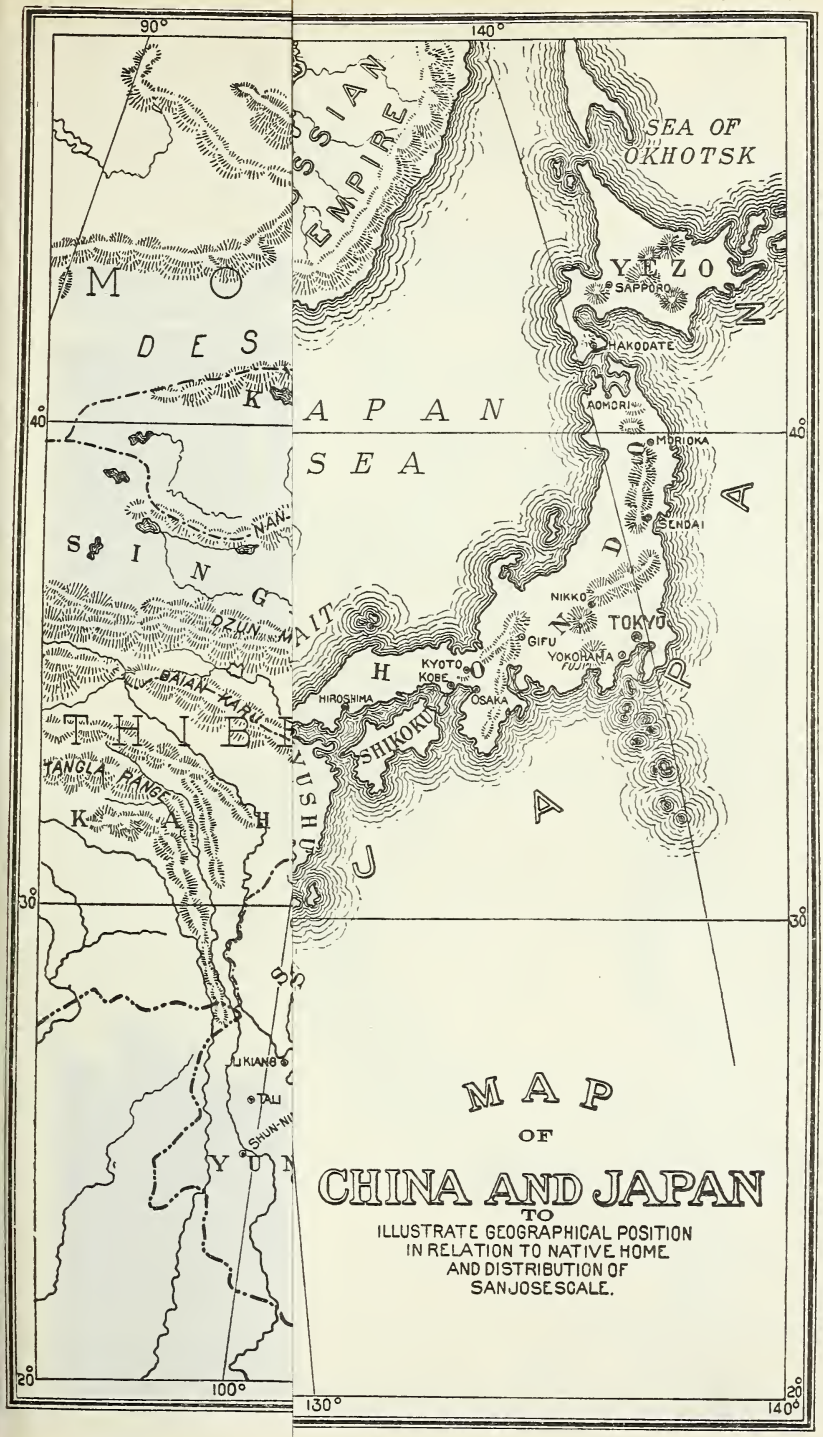
During the time spent in Japan, from April to September, 1901, the writer visited some forty-two provinces, and explored all the principal islands, representing a stretch in latitude the equivalent of from northern Maine to Florida. Altogether these explorations enabled him to make a pretty correct judgment on the San Jose scale problem in Japan. Japan is not especially a horticultural country. Her comparatively enormous population of 46,000,000 compels the growth of cereals and other necessities of life wherever possible. Very little land, therefore, is devoted to fruit raising, and fruits are considered as luxuries. Nevertheless, practically every dwelling house in Japan has a little dooryard or kitchen garden in which are single examples of cherry, plum, peach, persimmon, and other trees. Furthermore, the roadways and temple grounds and streets are lined with cherry and plum trees, planted for bloom and ornament and not for fruit. There are orchard districts in Japan of limited extent. In northern and central Japan there are a few peach orchards and a few orchards of native pears, and in southern Japan small orchards of orange, pomelo, walnut, and other fruits. In old Japan the chief deciduous fruit is a native pear grown in small patches of from a fraction of an

[a] See Bul. No. 20, new series, Div. Ent., U. S. Dept. Agric., pp. 36–39, 1899.

acre to 2 or 3 acres in extent. These are trained low on overhead trellises (Pl. III), and at a short distance look like vineyards. There are several districts where such orchards occur in considerable numbers. These orchards are very ancient, many of them having trees more than one hundred years old. If the San Jose scale were native to Japan it would occur in these pear orchards, the pear being one of the favorite food plants of this scale insect.

In northern Japan, including the island of Hokkaido, and the northern end of the main island, Hondo, apple raising has been introduced in modern times very much on the lines followed in this country. Prior to the opening of Japan to foreign commerce and exploration the apple as an edible fruit was unknown in that country. The orchards in northern Japan are chiefly, therefore, of American origin and represent American varieties. Most of the stock came from California, and much of it was undoubtedly infested with San Jose scale when it was received. There is, therefore, thruout these northern apple orchards a mild infestation with this scale. The Japanese are very enthusiastic in their efforts to gain all the benefits of western civilization, and this is shown in horticultural as well as in other fields. The three leading nurseries, therefore, of Japan have been very active during the last twenty or thirty years in importing the different varieties of pear, peach, and apple from America, and all three of these nursery districts have become infested with San Jose scale, evidently from such importations from California, where the scale has been widely distributed for thirty years. Outside these nurseries, however, in central and southern Japan, the San Jose scale did not occur, except where it had been introduced on new stock from the nurseries referred to. The old native pear orchards were free from scale, except where replants had been made of American varieties, or new native stock, to fill in breaks in the orchards. The infestation was very often just beginning and immediately surrounded the replants. In all Japan, therefore, in the little house gardens and temple grounds where were cherry, plum, and other trees suitable for San Jose scale, this insect did not occur, except where the evidence was very plain of its recent introduction as indicated. Without going into details of the evidence, it is sufficient to say that the conditions in Japan are essentially the same as in this country. The San Jose scale is a recent comer. It was, in fact, not known in Japan prior to the year 1897, when its presence there was first determined, but it has now been scattered pretty widely by nursery stock, exactly as in this country, and occurs under similar conditions; in other words, only where it has been recently introduced. The investigation showed very distinctly that Japan could not be considered responsible for the San Jose scale.

The results and conclusions arrived at by the writer were afterwards fully confirmed by a very thoro and painstaking explora-



MAP OF CHINA AND JAPAN

TO ILLUSTRATE GEOGRAPHICAL POSITION IN RELATION TO NATIVE HOME AND DISTRIBUTION OF SANJOSE SCALE.

MAP OF CHINA AND JAPAN TO ILLUSTRATE GEOGRAPHICAL POSITION IN RELATION TO NATIVE HOME AND DISTRIBUTION OF SANJOSE SCALE.

MONGOLIA
GOBI DESERT
KANSU
ALASHAN MTS.
GREAT KHINGAN MTS.
EASTERN GOBI
TSITSIKAR
MANCHOORIA
RUSSIAN EMPIRE
SEA OF OKHOTSK
KIRIN
YEZO
SAPPORO
HAKODATE
MUKDEN
SHEN-KING
GREAT WALL
SHAN HAI QUAN
PEKIN
PE CHI LI
GULF OF PE CHI LI
TIENSIN
TUNG KU
PAO-TING
JAPAN SEA
AOMORI
MORIOKA
SENDAI
KOREA BAY
SEOUL
KOREA
NIPPON
NAN-SHAN MTS.
SINGHAI
SNOW MTS.
THAI-YUAN
SHANSI
Yellow River
SHANTUNG
TSINAN
KAIO-CHOU
CHIFU
WEI HAI WEI
YELLOW SEA
NIKKO
TOKYO
GIFU
YOKOHAMA
KYOTO
KOBE
OSAKA
HIROSHIMA
SHIKOKU
KYUSHU
NAGASAKI
KUMAMOTO
KAGOSHIMA
KOREA STRAIT
DZUN-MO-LUN MTS.
BAIAN-KARU MTS.
PE LING MTS.
KAHI-FENG
SINGAN
HO-NAN
KIANGSU
NANKING
Yang tse Kiang Riv.
SHANGHAI
TIBET
YANGLA RANGE
KUN LUN MTS.
KIOO LONG SHAN MTS.
HO-PEH
CHING-TOO
SNOWY MTS.
WU-TCHANG
NGAN-KING
HANG-CHOW
KOW KIANG
CHANG-SHA
NAN-CHANG
CHINA
QUEI-CHOW
QUEI-YANG
NAN LING
QUEI-LING
MELING MTS.
TUNG KOO YEN (CHEKIANG)
FUCHAU
FORMOSA STRAIT
TAI-PE
FORMOSA
RYUKYU ISLANDS
YUNNAN
YUN-NAN
KUKIANG
TALI
SHUN-NING
CHU-HSIUNG
CHENG KIANG
QUANG-SE
CANTON
Si kiang R.
MACAO
HONGKONG
100°
110°
120°
130°
140°
90°
40°
30°
20°

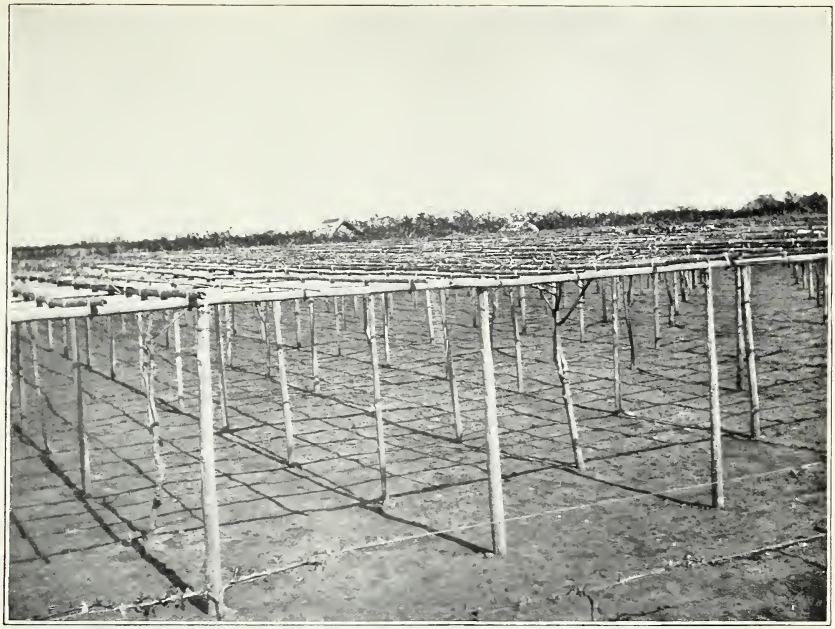


FIG. 1.—JAPANESE APPLE ORCHARD, SHOWING TRELLIS METHOD OF TRAINING.
(AUTHOR'S ILLUSTRATION.)

FIG. 2.—OLD NATIVE PEAR ORCHARD OF JAPAN, SHOWING METHOD OF TRAINING.
(AUTHOR'S ILLUSTRATION.)

tion of the entire Japanese Empire conducted by Japanese entomologists under the authority of the Imperial Agricultural Experiment Station in Japan. The publication giving the results of this investigation[a] is a very interesting and valuable contribution to our knowledge of the subject, and is illustrated by numerous maps and figures.

EXPLORATIONS IN CHINA.

Investigations up to this point, while freeing Japan from the onus of giving the San Jose scale to the world, left the problem unsettled as to the original home of this insect. China remained as the most likely place of origin, and the writer proceeded to China to continue his explorations there. While in Japan a good deal of information was gained relative to fruit conditions in China, from English, German, and American residents who were spending the summer months in Japan to escape the rather trying climate of China. In brief, it may be stated that deciduous fruits are grown from the Shanghai region northward, the peach being practically the only fruit grown to any extent about Shanghai. The great apple district of China is the region lying back of the city of Chifu in the north. This apple-growing industry was started many years ago by a missionary, Doctor Nevius, and has assumed very considerable proportions and covers a good deal of the province of Shantung. Below Shanghai the orange and other subtropical fruits replace the deciduous varieties. North of Chifu native fruits only are grown, consisting of the native pear and peach, and such wild fruits as wild crab apples and an edible haw apple.

A very considerable exploration of the country lying immediately back of Shanghai was made in the course of a long house-boat trip. A great many peach orchards were examined and a good deal of miscellaneous fruit and other plants growing about house yards were inspected. Nowhere was there any evidence of the San Jose scale, nor were scale insects of any sort much to be seen. The climate of this region is unfavorable for such insects and they are normally killed out by fungous disease. The writer afterwards proceeded by boat to Chifu—a five-day ocean trip from Shanghai, and made a considerable exploration thruout the apple orchards of this region on horseback, visiting, among others, the original orchards planted by Doctor Nevius. In all these the San Jose scale was found scatteringly present, not, however, doing any special damage, and probably not enough to be noticed, if its possibility for evil was not so well established. The presence of the San Jose scale in this region did not, however, have any special significance, since much of the original

[a] The San Jose scale in Japan. Imperial Agricultural Experiment Station, Tokyo, 1904.

stock was obtained from California, and doubtless from nurseries which were infested with the scale.

The journey of exploration was continued northward to Tientsin and Pekin. In this region the San Jose scale was found on native plants also, including the flowering peach, a tree grown for ornament solely, and not for fruit, and notably on the native fruits in the markets in these cities.

The markets of Pekin were of especial interest in this connection. Pekin is the center and market for all the region lying to the north and west, and the streets (Pl. IV, fig. 2) devoted to the sale of fruits and other products in the Chinese city are one of the great show places. The fruit and nut products are brought into Pekin in little two-wheeled carts (Pl. IV, fig. 1), or more generally on camelback, great caravans of heavily loaded camels and streams of carts constantly entering the city with the products of the outlying provinces. One finds, therefore, in the markets of the Chinese city the fruit products of all northern China, and can study them at ease. All the district lying between Pekin and the great wall, north and west and east, has been most carefully explored and mapped by the foreign military authorities. From various individuals employed in this minute survey a great deal was learned relative to the fruit growing in the district indicated. Much of the fruit found in the markets of Pekin comes from the hill region leading up to the mountains separating China from Mongolia and Manchuria. These fruits are native apples, pears, and peaches, and the little haw apple already mentioned. Great quantities of these fruits were examined in the market, with the exception of the peach, which was then out of season, and later similar examinations were made at Tientsin. A very scanty but general infestation with San Jose scale was found on the different fruits examined. Perhaps one apple in a hundred would have a few of these scales about the blossom end and the same proportion was true of the haw apple and the native pear. Thruout the region where these fruits are grown there has been no introduction of foreign stock. The occurrence of the San Jose scale on these two fruits was conclusive evidence that in the region whence they came the San Jose scale is native. The scattering occurrence of the scale also indicated, as would be anticipated, that this pest in its native home is kept in check by natural means.

The investigations made at Shanghai, and later southward to Hongkong, the Malay Peninsula, and Java, indicated that the San Jose scale in eastern Asia can not survive below Shanghai.

The special district where it is native and thrives is a fairly well shut-off region, which probably accounts for the failure of this insect to become a world pest ages ago. This district is the region leading up to the mountains and comprising the northern and northeastern

FIG. 1.—PONY FRUIT CART IN WHICH PRODUCTS OF THE HILL COUNTRY ARE BROUGHT INTO PEKIN, CHINA. (AUTHOR'S ILLUSTRATION.)

FIG. 2.—PORTION OF STREET DEVOTED TO SALE OF FRUITS IN PEKIN, CHINA. (AUTHOR'S ILLUSTRATION.)

[In foreground, fruit samples; in background, storehouses, also dromedaries employed to bring products from remote provinces.]

frontiers of China proper. Beyond the great wall on the north and west lies Mongolia, consisting chiefly of the vast Desert of Gobi. To the northeast, and separating the region from Manchuria and Korea, is the eastern Gobi Desert. To the south and east lies the great alluvial plain, the product of centuries of mud carried down by the Yellow River, a region where cereals only are grown. These are all effective barriers, and especially so when considered in connection with the political conditions of the past. We have, therefore, as the original home of this insect a naturally shut-off area from which it could not easily escape under the conditions prevailing up to our own times.

The means by which the San Jose scale came from China to America is a matter of interest. As previously stated, it is believed that this pest reached California on trees imported by the late James Lick. It is the writer's belief that Mr. Lick imported from China, possibly thru Doctor Nevius, with whom he was probably in correspondence, the flowering Chinese peach, and brought with it the San Jose scale to his premises. Undoubtedly this scale insect came to this country in some such way on ornamental stock from China.

RECORD OF THE SPREAD OF THE INSECT.

No attempt will be made to trace the details of the later extension of the San Jose scale, but the earlier history of this scale in the United States is well worthy of record as is also a summary at least of the means by which it became so widely and disastrously distributed so shortly after its first appearance on the Atlantic side of the Continent.

HISTORY IN CALIFORNIA AND THE WEST.

The spread of the San Jose scale from the point of original infestation in the San Jose Valley was somewhat rapid, its area increasing in every direction, but more rapidly toward the north and the west. By 1873 it had become a serious pest in orchards which had direct connection with that of Mr. Lick, and in 1880, when Professor Comstock studied it, he reported that he had never seen any other species so abundant and injurious as this was in certain orchards. As reported by Mr. Coquillett, it had extended as far west as San Francisco by 1883, but it had not reached important deciduous-fruit districts in southern California three years later. Prior to its reaching the East in 1886 or 1887 it had slowly extended its range on the Pacific coast and in States west of the Rocky Mountains, including California, Oregon, Washington, and Idaho on the north, and Nevada, Arizona, and New Mexico on the south. In the early nineties it had penetrated into British Columbia.

HISTORY IN THE EAST.

The general records of the discovery of the insect in the East are reproduced, with slight changes, from Bulletin 3.

The occurrence of the San Jose scale in the East was first discovered early in August, 1893, in the grounds of Dr. C. H. Hedges, of Charlottesville, Va. An infested pear had been sent by Doctor Hedges to Mr. Galloway, chief of the Division of Vegetable Physiology and Pathology of the Department of Agriculture, on the supposition that it was affected by a fungous disease. The fruit was submitted to the then acting entomologist, Doctor Howard, who immediately recognized the injury as due to the San Jose scale, and the startling and deplorable fact was established of the introduction into eastern orchards of this worst scourge of deciduous trees of the Pacific Slope, as well as the fact that it was evidently able to maintain itself in a supposedly less favorable climate. The importance of this discovery was at once realized, and two agents of the Bureau, Messrs. Schwarz and Coquillett, were detailed to make a thoro investigation. In conjunction with the State board of agriculture of Virginia and under the supervision of Mr. Coquillett a thoro fumigation with hydrocyanic acid gas was given to the infested trees and plants.

The introduction of the scale was subsequently traced to currant bushes purchased from a New Jersey firm.

In March, 1894, the presence of the scale was determined by Doctor Howard, at Riverside, Charles County, Md., in a rather large orchard situated on the river front, and including over two thousand peach and several hundred apple trees. This orchard was visited by the writer, who found that many of the trees were infested with the San Jose scale, large numbers having already perished. The infested stock was again in this instance traced to a New Jersey nursery. This orchard, on account of its proximity to Washington and the facilities thus afforded for experiment, was used by the Bureau in the testing of various washes for this scale.

During the same month (March, 1894) specimens of the San Jose scale were received from De Funiak Springs, Fla., thru the entomologist of the Florida Experiment Station, Mr. P. H. Rolfs. The late Mr. H. G. Hubbard, one of the assistants of the division, visited the infested locality and found the scales confined chiefly to peach and plum, occurring, however, in small numbers on Kieffer pear, pecan, and persimmon. Many thousands of trees were found to be infested, including nearly every orchard within a radius of 5 or 6 miles. The source of the infestation in this case was not definitely ascertained, but it was evident after examination that some infested nursery had sent a shipment of trees, and the indications were that

there had been repeated importations, the first indication of injury having been noted six years before.

On receipt of the Florida specimens Doctor Howard concluded that as the scales had been found in three such widely separated localities, and as the information gained from the owners of two of the affected orchards led to the supposition that the original stock had been obtained from a large eastern nursery, the probabilities were strong that the scale had established itself in many eastern points during the preceding five or six years. He therefore immediately prepared a circular of warning and had nearly 12,000 copies mailed early in April to all eastern agricultural newspapers and to very many eastern fruit growers. As a result of the issuing of this circular many new localities for the scale were ascertained, a widespread interest in the subject was aroused, and careful investigations were made in all the States to which there was any likelihood that the insect had been carried by nursery stock or other means.

By the end of August, 1894, the scale was known to occur in the following localities in the East: In a rather widely extended district in Florida, one locality in Virginia, three in Maryland, one in Indiana, two in Pennsylvania, many in New Jersey, and one in New York, on the east bank of the Hudson River a little below Albany. Very shortly afterwards, during the same summer, it was found on Long Island, occurring both in orchards and nurseries. Later in the fall the scale was found at three new localities in Maryland, and still later specimens were received from the extreme southern part of Georgia. In December Professor Webster reported receiving the scale from a large orchard district in southern Ohio, and a little later specimens were received from Jefferson County, Ind. The scale was found also near New Castle, Del., in January, 1895, and additional localities were discovered during the following spring and summer of 1895 in some of the States mentioned, as also in Alabama, Louisiana, and Massachusetts. In nearly every instance the source of infestation in the East was the same, namely, one or the other of two important New Jersey nurseries.

PRINCIPAL SOURCES OF INFESTATION IN THE EAST.

As stated, nearly all the eastern occurrences of the San Jose scale were traced to two large New Jersey nurseries, from which infested stock had unwittingly been sent out broadcast for certainly six or seven years. The damage thus done to the fruit interests of the East by these nurserymen can hardly be estimated, and yet it must be admitted that they were, in a measure, blameless, since they were undoubtedly entirely unaware of the dangerous character of the scale insect which infested their stock. We can hardly avoid the conclusion, however,

that they were aware that they were distributing diseased stock, since to deny this presupposes that the stock received no examination. If the scale was noticed it was doubtless supposed to be one of the common eastern species, which, while bad enough, are of little importance compared with the San Jose scale.

The two nurseries responsible for the original eastern introduction of the scale became infested in the same way. Either in 1886 or 1887, in the endeavor to secure a thoroly curculio-proof plum, both of these nurseries introduced from California an improved Japanese variety, the Kelsey, obtained from the San Jose district. We have the statement from the proprietors of one of the nurseries that the plum trees in question were secured in the spring of 1887 from San Jose, Cal., and were shipped thru the agency of a Missouri nursery company, which acted in this instance apparently as a mere transmitting agent. The trees were unquestionably thoroly infested when received, did not thrive, and in both cases most of them were ultimately taken out and destroyed. The stock, however, had been multiplied by nursery methods, and from the original stock, and that subsequently obtained, the scale spread more or less completely thruout both of the nurseries in question. Both of these firms, when the nature of the infestation was brought to their attention and the seriousness of the damage they were doing was made apparent to them, undertook measures to exterminate the scale.

In addition to the two prominent nurseries mentioned, several smaller nurseries in the East were found to harbor this scale. Some of these had been recently infested, but in others the infestation was of long standing. Three nurseries of the latter class were located on Long Island, and apparently received their original scales from New Jersey; one in Florida, reported by Prof. P. H. Rolfs, and two in Georgia apparently received infested stock from eastern sources, and one or more each in Louisiana, Mississippi, and Alabama became infested with the scale thru pear stock coming from Lewiston, Idaho. In Massachusetts there were infested nurseries at Cambridge and Bedford, the origin of the scale in these cases being obscure; and a nursery in Missouri was under suspicion as having been the agency thru which the original infested Japanese plums were transmitted to eastern nurseries. Two infested nurseries were known to exist in Maryland also.

SUMMARY, BY STATES AND TERRITORIES, OF DISTRIBUTION AND PRESENT CONDITION.

The detailed facts relating to the first introduction of the San Jose scale into the several States are given in Bulletins 3 and 12, and with greater minuteness in the various publications of the experiment stations of the several States involved. The distribution has now become

so general in most of the States where the San Jose scale has occurred for a number of years that it is impracticable to indicate the different points of infestation, and even in the States worst infested many orchards are free from the scale; but if an attempt was made to graphically picture the distribution on a map, the points of infestation would be so numerous as to give the appearance of absolutely complete infestation. The publications cited may be referred to, therefore, for the more detailed and complete records. A mere statement of the present general status of the San Jose scale in the several States in which it occurs will now be given. This statement is based on replies to a circular letter of inquiry sent to State entomologists and experiment station officers in May of this year.

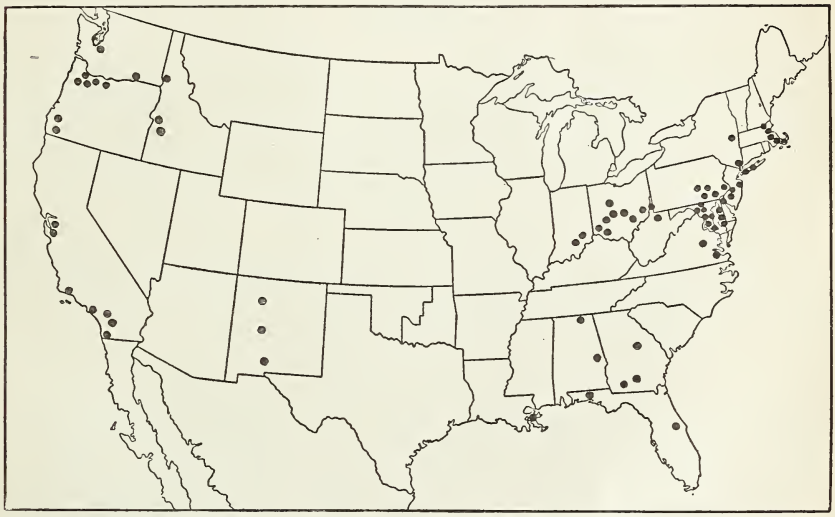


FIG. 1.—Map of the United States, showing localities known to have been infested with the San Jose scale up to 1896. (Original.)

It is interesting for comparison to reproduce the map (fig. 1) showing the known distribution at the time of the publication of Bulletin 3 in 1896, when the scale was reported in only 20 States and in comparatively few localities in each, with the single exception of New Jersey, which had been most energetically inspected by Dr. John B. Smith and found to be very generally infested. Bulletin 12 records the scale occurring in 33 States and also in the District of Columbia and Canada, and in very many new localities in all of the States previously recorded as harboring the scale. The number of actual records of the San Jose scale now available are many hundredfold what they were at the time of the publication of Bulletin 12 at the beginning of the year 1898.

There are still a few States in which the San Jose scale does not now occur or has not been reported, namely, Colorado, Maine, Minne-

sota, Nebraska, North and South Dakota, Wisconsin, and Wyoming. It probably occurs in some of these States, however, altho it has so far escaped notice.

ALABAMA.

The occurrence of the San Jose scale in Alabama was first indicated in April, 1885, by material received from Prof. J. W. Hoffman, of the Tuskegee Institute, Tuskegee. As now reported by Mr. R. S. Mackintosh, State horticulturist, the infestation is scattering thruout the State, but chiefly along some of the main railroad lines, and most of the infested orchards became so before people knew about the scale and before the adoption of quarantine measures to prevent its introduction and spread.

ARIZONA.

The San Jose scale has been present in Arizona in the older orchards of the Salt River Valley for more than twenty years. Director R. H. Forbes, of the agricultural experiment station, now reports that this scale insect has rather dropt out of sight, probably because of the succession of excessively hot dry years from 1899 to 1904, inclusive. During this period a large proportion of the deciduous fruit trees, including almonds, peaches, pears, apricots, and apples, perished, apparently from lack of irrigating water and partly from the effect of extremely high temperature and dryness.

ARKANSAS.

The presence of the San Jose scale in this State is recorded in Bulletin 12 (1898), on material reported by Professor Stinson. Mr. C. F. Adams, the entomologist of the agricultural experiment station, now states that the spread of this insect is still not very general; that it has been reported from several counties, and that he has seen it in two florists' establishments, but has not found it in any of his nursery inspection.

CALIFORNIA.

The San Jose scale has, of course, long been generally disseminated thruout the State. Prof. C. W. Woodworth, entomologist of the agricultural experiment station, now reports that it does not occur at Berkeley, but probably occurs everywhere else in the State where fruit trees are grown, except in isolated plantings in the foothill regions. Usually it is not seriously troublesome, tho it may increase rapidly at any time and become a pest. The uniform treatment with the lime, sulfur, and salt wash keeps it in check, and parasitism is often fairly efficient. In some districts, as about San Jose, where it has almost disappeared, the result may be due both to parasitism and to some

obscure form of disease as well as to the lime-sulfur treatment. In southern California it is particularly troublesome in apple orchards. The principal variety of apple grown is the White Pearmain, and the comparatively rough bark of this variety makes it difficult to get very satisfactory results from the lime-sulfur wash. The varieties of apple commonly grown in northern California—for example, Newton Pippin and Yellow Bellflower—are smooth barked, and better results with the wash are gained. Taking the State as a whole, Professor Woodworth says that it will be readily found in at least 25 per cent of the orchards, in injurious numbers in probably 10 per cent in any one year, and that from 25 per cent to 40 per cent of the orchards are sprayed with the lime, sulfur, and salt wash every year.

COLORADO.

The San Jose scale has apparently not yet obtained foothold in Colorado, but it has been sent to us from Colorado on fruit imported from California. The probable explanation is that the fruit regions of Colorado are above the climatic range of this scale insect.

CONNECTICUT.

The San Jose scale is recorded for at least five localities in Bulletin 12. The increase of this scale in Connecticut has been pretty rapid, and Mr. W. E. Britton, State entomologist, expresses the belief that there is now no town in the State which is not infested, tho he may not have records from quite all of the towns. It is found very generally, at any rate, in all of the larger cities, which are thoroly infested. Practically all of the larger orchards are infested, tho perhaps only slightly. He says that there are many orchards and trees which are still exempt, but that there is no general region of the State where the scale can not be found.

DELAWARE.

Delaware, as recorded in Bulletins 3 and 12, became generally infested very early. Mr. Wesley Webb, secretary of the State board of agriculture, now informs us that the San Jose scale occurs in all parts of Newcastle County and in approximately one-half of the orchards. In Kent County there are many young peach orchards, and more than one-half of them are infested to a greater or less extent, a large proportion of them, however, only slightly so. In the western half of Sussex County, along the railroad from Farmington to Delmar, nearly half of the orchards are somewhat infested, while in the eastern half of the county from Lincoln southward there are but few orchards, and these are comparatively free from scale.

DISTRICT OF COLUMBIA.

The occurrence of the San Jose scale in the District is reported in Bulletin 12, and it is now pretty generally distributed on fruit trees in the city of Washington and its suburbs.

FLORIDA.

The occurrence of the San Jose scale in Florida was brought to our attention in March, 1894, as recorded in Bulletin 3, and additional localities soon followed. Mr. E. W. Berger, assistant entomologist of the State experiment station, reports that the present distribution is extensive, the scale occurring in some twenty-odd counties, or wherever peaches are grown.

GEORGIA.

The early records of Georgia infestation beginning in 1894 are given in Bulletins 3 and 12. The San Jose scale in 1894 had a pretty strong foothold in this State. The recent conditions in Georgia are indicated on a map prepared by Mr. Newell and published in the proceedings of the Twenty-eighth Annual Meeting of the Georgia State Horticultural Society, in 1904. This map indicates very general infestation thruout the State, including most of the counties where fruit growing is of any importance. Prof. Hugh N. Starnes, in a letter transmitting this report, states that the large increase indicated on this map does not mean that infestation is still progressing, but merely that it has been more definitely located and the present State laws looking to the control of this pest are ample in their provisions and are being rigorously enforced. Mr. Newell reports in this connection that during 1904 out of a total of 218 nurseries inspected, only 9 were found infested, and that this is a very considerable reduction from the percentage of infestation shown by records of previous years.

IDAHO.

The infestation in this State is directly from western sources and is of long standing, at least in the limited area about Lewiston, where the oldest orchards are located. Mr. L. F. Henderson, the entomologist of the State experiment station, reports on the present situation under date of May 29 as follows:

> The scale is very prevalent along the lower river bottoms, such as Lewiston on Clearwater, Juliaetta and Kendrick on Potlatch River (a tributary to Clearwater), up and down the Snake at Weiser, Payette, Caldwell, Nampa, as far as Glenns Ferry, possibly farther. Its eastern limit *seems* about Mountain Home, as I do not know of it at Shoshone. It does [not?] exist on the upper Snake, as Blackfoot, nor in the extreme southeast, as Montpelier. The elevation of this district seems too high for it, as it varies from 4,000 to 7,000 feet altitude. The altitude seems also too high about

Moscow and Rathdrum, tho this altitude (2,500 feet) is not more than at Weiser and Boise. Possibly greater rainfall in these last districts discourages it. At any rate, while it has existed at Lewiston for fifteen years, it has not ascended to Genesee, 12 miles distant, but nearly 1,800 feet higher.

In many places it is being well controlled in the orchards, where careful and systematic spraying with lime-sulfur spray is done.

ILLINOIS.

The San Jose scale was located in Illinois in 1896 by Professor Forbes, who, at the end of the following year, had found the scale in 22 colonies in 11 counties, as reported in Bulletin 12 of this Bureau. In a recent letter Professor Forbes gives the details of the present infestation, which may be briefly summarized as follows: One-half of the counties (51 of the 102) of the State are now known to be more or less infested, but 43 per cent of the infested orchards are included in 2 of these counties and 80 per cent in 5 counties, and in 30 of the counties listed the average number of infested orchards is but $3\frac{1}{3}$. In four of the counties the infestation is found only in one or more towns and not in orchards. It will be seen from this statement that while the San Jose scale is pretty widely scattered thruout the State, as it is also in adjoining States, it is far from having gained a general foothold save in a few counties, and even in the worst counties infestation is not yet general. In no States has inspection and remedial work been carried out more thoroly than in Illinois, and this accounts for the rather favorable conditions, in view of the fact that probably nearly all of the infested orchards and districts have been located.

INDIANA.

The first case of infestation was brought to our attention in May, 1894, and subsequent records are indicated in Bulletins 3 and 12. As indicated in a map sent by Prof. J. Troop, horticulturist of the State experiment station, the scale is now distributed over the entire State, occurring, however, in less than half of the counties. It occurs in all the Ohio River counties, and Vanderburg is indicated as the one worst infested.

IOWA.

Iowa hitherto has been one of the western States supposedly free from the San Jose scale. The State entomologist, Mr. H. E. Summers, reports that he now knows of but one infested point in the State, confined to a single orchard in Louisa County. Some other cases of introduction of the scale were discovered a few years ago, but were treated in such a thoro way that reinspection during the last three years has shown no further development of scale. No San Jose scale has been found in any nursery in the State.

KANSAS.

Kansas has long belonged to a group of middle western States free from the San Jose scale. During the present year, however, this scale insect has been sent to us for determination from Dodge City on apple twigs, which is the first and only record so far for this State, on the authority of Prof. E. A. Popenoe, entomologist of the State experiment station. A general examination of the orchards of the State has been begun, however, and additional records will probably be discovered.

KENTUCKY.

But one record of the San Jose scale was known in Kentucky at the time of the publication of Bulletin 12. Professor Garman, State entomologist, now reports that the scale is still not generally distributed in the State, and the credit for this he believes is due to the prompt institution of nursery inspection shortly after the San Jose scale came into prominence in the East. Within the past four or five years, however, he reports an increase in the number of infested localities, particularly in northern counties, and is inclined to believe that in some cases the stock condemned on the other side of the river is brought over and distributed on the Kentucky side. The infestation is confined to the river counties and some half a dozen interior counties, all lying rather above the median line of the State.

LOUISIANA.

The early records of infestation in Louisiana are given in detail in Bulletin 3, and the scale is supposed to date in this State from about 1891, as there recorded. The present situation as given by Mr. Wilmon Newell, the entomologist of the State experiment stations, indicates 12 distinct localities of occurrence, ranging from the northern line of the State to New Orleans. These points are widely separated, and the State is comparatively free from the scale. Mr. Newell states that no very thoro inspection of all the orchard sections of the State has been made, but that from the work already done he believes that not over 5 per cent of the orchards, at the outside, are infested. But one small nursery is known to be infested, and the owner of this nursery is not permitted to place his stock on the market.

MAINE.

The San Jose scale has never been reported from Maine, and this is confirmed in a recent letter from Miss Edith M. Patch, the entomologist of the State experiment station.

MARYLAND.

Maryland early became one of the eastern States worst infested by the San Jose scale, and one that suffered most, perhaps, from this pest. It also received the most energetic early work in efforts at extermination and control. The present situation, as indicated by Mr. T. B. Symons, State entomologist, shows the San Jose scale to be generally distributed over the entire State, with the exception of the two extreme western counties, Garrett and Allegany, the former having the San Jose scale at 2 points and the latter at 15. By the method of employing State inspectors in the various counties, 1,500,000 trees of various kinds have been inspected each year for the past four years, and from the records thus gained 18 per cent of the fruit trees inspected are infested, and 65 per cent of the orchards, and this estimate is believed to be moderate.

MASSACHUSETTS.

The presence of the San Jose scale was determined in Massachusetts as early as April 25, 1895, as recorded in Bulletin 3. Additional records are given in Bulletin 12. Prof. H. T. Fernald, summing up the present situation, says that he was forced to give up the effort of keeping a complete list of localities known to be infested in 1900, finding that the scale was practically everywhere in Massachusetts east of the Connecticut River. At the present time it may be found in almost every town to the western boundary of the Connecticut Valley, say 15 miles west of the river on the average. In Berkshire County, which lies west of this, he has no records, but he would not be surprised to find it somewhere in that region, particularly along the Housatonic Valley. As to percentage of infestation, he says that about one-third of the orchards are infested to a greater or less degree, and the infested orchards are particularly the more recently planted ones. In the older orchards infested replants may occasionally be found. Many of the cases of infestation, however, are of ornamental trees and shrubs in house lots. He states that from such places as the Arnold Arboretum and the Metropolitan Park system around Boston, which have had the scale for nearly fifteen years, it has spread in all directions, and that in Massachusetts it is less an orchard problem than one of ornamental plants.

MICHIGAN.

Michigan was not known to be infested at the time of the publication of Bulletin 3, but Professor Barrows, in August, 1897, reported 14 localities in 10 counties, the evidence showing that the scale had been present in the State since 1890. The present situation is indicated on a map prepared by the entomologist of the State experiment

station. Mr. R. H. Pettit, with the assistance of Professor Taft, and shows scattering infestation thruout the southern third of the State, the points farthest north in the interior away from the influence of Lake Michigan being at Ithaca and Otter Lake, which are both rather beyond the anticipated range of the scale insect. It is not shown, however, that the extreme points in the range are points of permanent infestation.

MINNESOTA.

The San Jose scale has not been reported from Minnesota.

MISSISSIPPI.

Mississippi apparently became infested with the San Jose scale at the same time (1891) and from the same material which carried this pest to Louisiana. Mr. Glenn W. Herrick, professor of biology, Agricultural College, Miss., now reports the scale from 16 localities in 15 counties. It is probable, however, that in portions of Mississippi and Louisiana the San Jose scale will not become nearly as serious a pest as in northern localities, on account of the action of fungous diseases.

MISSOURI.

The occurrence of the San Jose scale in 16 localities, as reported by Professor Stedman, is noted in Bulletin 12. Mr. Stedman now states that the San Jose scale has practically overrun the whole of St. Louis County, and that there is a bad case of infestation south of Independence, another just west of Cape Girardeau, and one near Charleston.

MONTANA.

The San Jose scale has never been reported from Montana. Mr. R. A. Cooley, the State entomologist, reports that during his seven years in Montana he has been in touch with all parts of the State, and feels sure that if the San Jose scale occurred there he would have known of it. A few reported cases investigated have turned out to be of other species.

NEBRASKA.

The San Jose scale has so far not been found in Nebraska, as reported by Prof. Lawrence Bruner, "except on fruit that has been shipped in, principally from Colorado." In view of its nonoccurrence in Colorado, the fruit referred to must have come from California or elsewhere.

NEW HAMPSHIRE.

It was early hoped that the San Jose scale would not be able to infest much of the fruit regions of New England, but this hope seems to be diminishing, and Prof. Clarence M. Weed reports the San Jose scale as far north as the White Mountain region in New Hampshire,

to an extent that it is seriously destructive. The records of infestation show the occurrence of this insect in New Hampshire in the eastern part of Manchester, in Dover Point, and Intervale, and in nurseries at Dover, Epping, and Seabrook; also in trees from these nurseries at Rollinsford, Lee, and Durham. Mr. E. D. Sanderson, the present entomologist of the State experiment station, adds two additional localities, one in Newington and the other at North Danville. Mr. Sanderson reports that no orchard inspections have been made, and that as practically all of the nursery stock comes originally from outside of the State, many of the younger orchards are probably infested.

NEW JERSEY.

New Jersey, responsible for much of the original distribution of the San Jose scale in the East, early became generally infested, as recorded in Bulletins 3 and 12. Dr. J. B. Smith, State entomologist, reports that this scale now occurs thruout the State and probably in 90 per cent of the orchards. In a general way, he says, those districts that are longest infested are in a better condition than those that have become more recently infested, because growers in the first instance have learned how to deal with the insect to the best advantage.

NEVADA.

The occurrence of the San Jose scale in Nevada is noted in Bulletin 12 in gardens in the city of Reno. We have records also from Carson City dating from 1903 and 1904. Prof. J. E. Stubbs, director of the State experiment station, writes that the insect is fairly under control in the State. In 1904, he says, and prior to that time, its ravages in three or four counties were considerable, and farmers complained that they were losing their fruit on account of it. At the session of the legislature held in 1903 a law was past giving authority to the several counties to appoint an inspector of trees, especially fruit trees. In Washoe, Ormsby, Humboldt, Elko, and Lincoln counties these inspectors are said to have done pretty good work and to have checked the scale by spraying; especially was this true in the counties of Washoe and Ormsby.

NEW MEXICO.

The distribution of the San Jose scale in New Mexico has probably changed very little since the publication of Bulletins 3 and 12, and no late records have been received from this Territory.

NEW YORK.

The presence of the scale in New York was determined in August, 1894, and the early records are noted in Bulletins 3 and 12. The present condition of this scale insect in New York has been reported to

us by Messrs. M. V. Slingerland and E. P. Felt. Mr. Slingerland gives a long list of the infested localities received at the Cornell experiment station, and reports that in general Long Island, the Hudson River Valley, and Niagara County seem to be the worst-infested sections. Mr. Felt's records were made after consultation with Mr. Atwood, of the State department of agriculture, who has direct charge of nursery-inspection work. The following counties are reported as badly infested, either because of the pest being generally distributed thruout the entire county or else because of its inflicting considerable damage in certain restricted areas: Albany, Cayuga, Chemung, Columbia, Dutchess, Erie, Kings, Nassau, Niagara, Ontario, Orleans, Putnam, Queens, Rensselaer, Richmond, Rockland, Suffolk, Wayne, Westchester, and Yates. It is also known to occur in the following counties: Broome, Chautauqua, Delaware, Fulton, Greene, Jefferson, Madison, Monroe, New York, Oneida, Orange, Schenectady, Schoharie, Schuyler, Seneca, Steuben, Tompkins, Ulster, and Washington. Mr. Felt reports that the scale may be safely said to be present in most sections where fruit interests are at all extensive, tho not always generally distributed.

NORTH CAROLINA.

The first records of the occurrence of the San Jose scale in North Carolina are given in Bulletin 12. Mr. R. S. Woglum, acting entomologist of the North Carolina department of agriculture, has submitted a map indicating general infestation thruout the State, represented by over fifty counties, in which the number of points infested range from 1 to 42. These points are definitely known either from personal observation or else from the receipt of specimens on plants. West of the Blue Ridge Mountains the region is quite free from the scale, only four infested localities being known.

NORTH DAKOTA.

No San Jose scale.

OHIO.

The early conditions in Ohio, as determined by Prof. F. M. Webster, are reported in Bulletins 3 and 12. Mr. A. F. Burgess, chief State inspector, gives the following summary of the present conditions:

Counties having no infested orchards	26
Counties with 1 infested orchard locality	27
Counties with 2 infested orchard localities	10
Counties with 3 infested orchard localities	10
Counties with more than 3 infested orchard localities or having large infested areas or numerous small outbreaks	15

The majority of the larger cities of the State are more or less infested.

These points of infestation cover the State pretty generally.

OKLAHOMA.

The first records of the San Jose scale in Oklahoma were received in 1904, on Japan plum from Mulhall. We have since received it, in 1905, on peach from Stillwater and El Reno. Mr. J. F. Nicholson, entomologist of the agricultural experiment station, reports that the scale has been found to a limited extent in five places in the Territory, namely, Mulhall, Shawnee, El Reno, Wellston, and Chandler. All of these cases are trees in city gardens.

OREGON.

Mr. A. B. Cordley, referring to present conditions in Oregon, states that to enumerate the localities where the San Jose scale is found would be practically to include all places where fruit is grown. He says that it occurs in a very large proportion of the orchards in western Oregon, from Ashland to Portland, particularly those along the lines of railroads or in the vicinity of towns, there being scattered orchards back toward the foothills which the San Jose scale has not yet reached. It occurs also between Portland and Astoria, along the Columbia River; is present in the Hood River Valley; in the Walla Walla Valley in the vicinity of Milton and Freewater, and in the Grande Ronde Valley in the vicinity of Vale and Ontario. There are, however, large areas of central and southern Oregon, remote from the railroads, where little fruit is grown, that the scale has not yet reached. It is noted, however, that the scale does no great injury except in small farm orchards or those that are neglected, and that in all the large orchards the lime, sulfur, and salt mixture as a winter spray is in general use.

PENNSYLVANIA.

The San Jose scale became early established in Pennsylvania from New Jersey nurseries, but the subject of San Jose scale control was not taken up as early in this State as in neighboring States, so that the conditions at the outset were not well known. Both Prof. H. A. Surface, economic zoologist of the State, and Mr. George C. Butz, the horticulturist of the agricultural experiment station, agree in the statement that the San Jose scale is now so widespread in Pennsylvania that there is scarcely a county that has not points of infestation. It occurs in practically all the important fruit regions of the State, and in many private and public grounds, especially in the portion of Pennsylvania lying east of the Allegheny Mountains. Mr. Butz reports that probably 20 per cent of the orchards are more or less infested. Professor Surface has, with the assistance of 30 inspectors, taken up active warfare against the scale, inspecting orchards and nurseries and trees in parks and giving demonstrations in methods of suppressing it. He states that he has not found the scale in the three northeastern

counties of the State, nor in some of the counties northwest of the center of the State, such as Cameron, Elk, Forest, McKean, and Warren.

RHODE ISLAND.

No records from Rhode Island had been received up to the time of the publication of Bulletin 12, in 1898, but Mr. A. E. Stene, of the College of Agriculture and Mechanic Arts, states that the scale has now spread over almost the entire State, and nearly every orchard where planting has been done in the last ten years is more or less infested. There are a few old orchards where no new trees have recently been set that are still free from the scale. It is believed that four-fifths of the orchards in the State are infested.

SOUTH CAROLINA.

But a single record for South Carolina had been received up to the time of the publication of Bulletin 12, largely, as there indicated, for the reason that there had been no State entomologist, and no work of inspection had been done. The records which have come to this office from South Carolina now number 10, and represent 7 different localities distributed miscellaneously over the State. Naturally, very few of the actual records would come to us, and the indications are that the State is pretty generally infested. Mr. C. E. Chambliss, the entomologist of the experiment station, now reports 24 infested localities, all of which had the scale prior to 1900.

SOUTH DAKOTA.

No San Jose scale has yet been reported from South Dakota. Mr. W. A. Wheeler, the entomologist of the experiment station, states that he has inspected nurseries of South Dakota for two years, and has not found the San Jose scale in any nursery. It has been introduced with stock received by the college from other States, but has always been speedily disposed of when received, and so far is not known to infest any of the orchards.

TENNESSEE.

A single locality was recorded for the San Jose scale in the eastern portion of the State in Bulletin 12. Since that time the number of records for the San Jose scale which have come to this office for determination has increased to 14. These are distributed generally over the State, and indicate rather widespread infestation, and naturally very much more than is shown by the material which has been sent to the Department.

A recent letter from Mr. G. M. Bentley, assistant entomologist, gives the information that no complete survey of the State has been

made, but, roughly speaking, 30 per cent of the nurseries are more or less infested, and in eastern Tennessee the San Jose scale is very generally present; but the section of the State, notably Franklin County, where most of the nurseries are located, is free from the pest. The extreme western part of the State, in the Memphis section, is also pretty badly infested. No general orchard inspection of the State has been made.

TEXAS.

Eight localities were reported for Texas in Bulletin 12. The scale is now fairly widely distributed in the State, the records of this office numbering 19, some of these, however, representing the same district. The localities cover, generally speaking, the eastern half of the State, namely, the nonarid portion where fruit growing is followed to a greater or less extent. Prof. A. F. Conradi, the State entomologist, has records of the insect's occurrence in Bexar, Brazonia, Calhoun, Cherokee, Comal, Comanche, Eastland, Erath, Galveston, Harris, Harrison, Hopkins, Hunt, Valverde, Wharton, and Wood counties.

UTAH.

No San Jose scale was recorded for Utah in either Bulletin 3 or 12. In 1899 it was sent to us for determination from both Ogden and Logan. Mr. E. D. Ball, the entomologist of the State experiment station, reports that he is unable to give the exact localities of the occurrence of this insect, but states that it is pretty widely spread in the central section of the State, doing, however, little damage. It seems to be controlled by the twice-stabbed ladybird. The commercial orchards, as a rule, are practically free. A good deal of spraying has been done with the standard lime-sulfur wash.

VERMONT.

The occurrence of the San Jose scale in Vermont was brought to our notice in 1899. Mr. William Stuart, horticulturist of the State experiment station, says that it is now known to occur in only two localities, namely, Charlotte, Chittenden County, and Orwell, Rutland County; in both instances occurring in only one orchard.

VIRGINIA.

The details of the early records in Virginia are given in Bulletin 3 and in Bulletin 12. A great many new records have been received from Virginia and more material has come to this Bureau for determination from Virginia than from any other State except Pennsylvania. Mr. J. L. Phillips, State entomologist, in reply to our circular letter refers

to his publications, in which it appears that the San Jose scale is recorded from 78 counties. Many orchards in all of the counties are still free from the scale, but infestation is very general thruout the State.

WASHINGTON.

The State of Washington was early infested with the San Jose scale from California, and at the time of the publication of Bulletin 3, in 1896, the fruit-growing regions were pretty well dotted with this pest. Mr. A. L. Melander, assistant entomologist, submits a map which is about to be published in a bulletin showing the distribution of this insect. It indicates the occurrence of the scale in the western settled section of the State, where fruit growing is important, following the river valleys, but with some important scattering districts on the west side of the mountains, where it seems to have a precarious foothold. It is little dreaded by orchardists, and fruit trees are commonly sprayed with the lime, sulfur, and salt wash in February, and one treatment is reported to be effective for several years.

WISCONSIN.

Wisconsin is, on the authority of Mr. E. P. Sandsten, horticulturist of the State experiment station, now free from the San Jose scale. The only occurrence of this pest in the State was three years ago, in the extreme southern part, and it was here stamped out by the prompt adoption of radical measures.

WYOMING.

Mr. B. C. Buffum, director of the agricultural experiment station, reports that the San Jose scale has not yet appeared in Wyoming. There are but few orchards in bearing, and these are believed to be free from this pest.

WEST VIRGINIA.

The San Jose scale was first noticed in West Virginia in 1896. Many examples of the San Jose scale in this State have been sent to this office for determination, showing the scale to be very generally distributed.

The recent reports of the West Virginia experiment station, notably those for 1903–4 and 1904–5, and later records received from the entomologist of the experiment station, Mr. W. E. Rumsey, indicate very general infestation thruout the State, conditions being similar to those in Virginia. Nevertheless, while there are hundreds of infested orchards and several infested nurseries, the great mass of the orchards and nurseries are still free from scale. A very careful nursery and orchard inspection is maintained in West Virginia, and

the actual conditions of infestation are perhaps as well known in this State as in any other. In many localities the scale is held in check by this careful system of inspection and by the prompt and thoro adoption of the remedial treatment.

CANADA.

On the authority of Dr. James Fletcher, the Dominion entomologist, the San Jose scale infestation in the eastern portion of Canada is confined to the Niagara Peninsula and counties along the north shore of the west end of Lake Erie. It has also been found in several localities in British Columbia, having reached this province in its northward migration along the Pacific slope.

THE RELATION OF CLIMATE TO SPREAD.

This subject was rather carefully considered in both Bulletins 3 and 12, in connection with the climatic districts or life zones established by Dr. C. Hart Merriam, within which particular animals thrive and outside of which they fail to establish themselves. These life zones as thus limited have a special value in indicating the probable spread of many injurious insects, and seem to be particularly significant in the case of the San Jose scale. These life zones are: The tropical, occupying small areas in Florida and southern Texas; the lower and upper austral, covering the bulk of the United States; and the transition zone, coming between the last and the boreal zone of Canada northward. These zones will be better understood by reference to the accompanying map (Pl. V). The early records led to the belief that the San Jose scale would be practically limited to the upper and lower austral zones, and that the important fruit districts in the northern United States and in elevated mountain regions, represented by the transition zone, would be slightly if any infested. In the main, the records of the distribution of the San Jose scale have confirmed this belief. Nevertheless, the scale has, in a number of instances, appeared well into the transition zone as fixt by Doctor Merriam, notably in Massachusetts, in New York, in Michigan, and a few other points; but in most of these cases the evidence gained from the relation of other animals and plants would indicate that the transition and upper austral zones were not correctly charted, so that in general the belief in the immunity of the transition zone holds.

As pointed out by Doctor Howard in Bulletin 12, the coastal law which brings about the intermingling of northern and southern forms will probably justify the eastern Massachusetts occurrences. Other occurrences in Massachusetts are justified by the river-valley law in relation to the Connecticut River, and Doctor Merriam admits that his line across the southern peninsula of Michigan is not very accurately

drawn. Special topographical conditions and protecting mountains will probably account for other divergences.

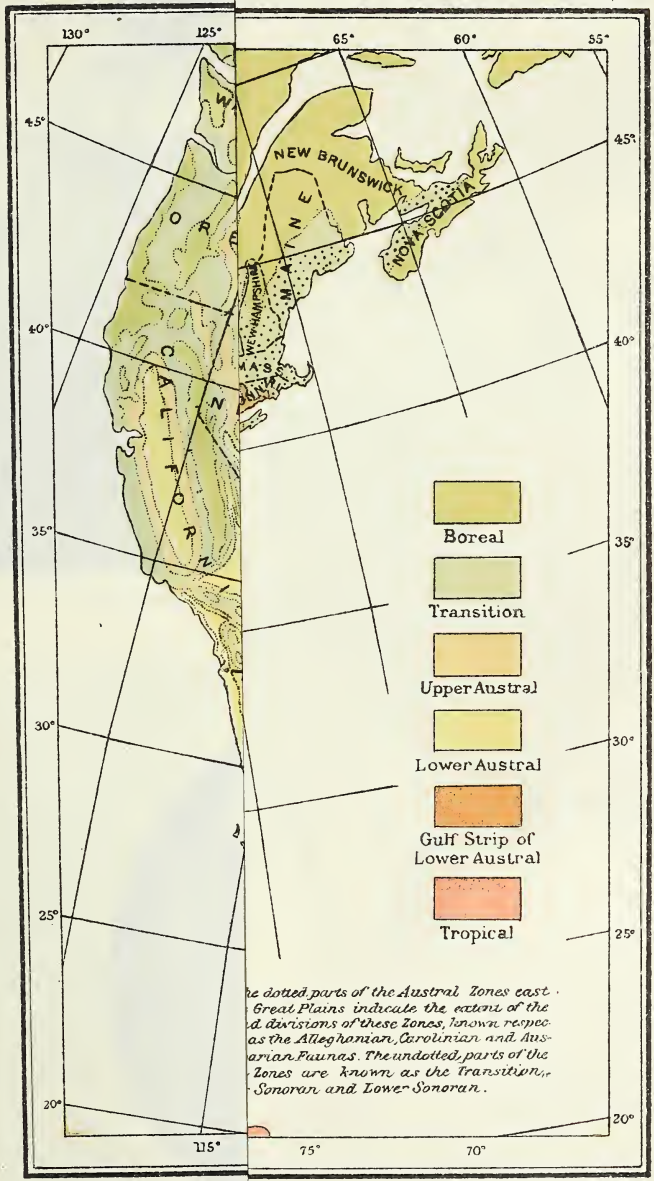
In the lower austral and tropical regions the San Jose scale, as pointed out by Doctor Howard, may not prove as injurious as in the upper austral, and this follows the general rule regarding armored scale insects in warm countries. Armored scales rarely appear or thrive in the moist Tropics, as shown by the explorations of the writer in the East and West Indies. Fungous diseases, which thrive in warm and moist climates, are the principal agency in keeping such scale insects in check, and in the case of the San Jose scale the common scale fungus *Sphærostilbe coccophila* has already done good work in Florida and other portions of the lower austral zone. Moisture is a prerequisite in the case of this disease, and little benefit comes from it in the drier portions of this zone. Too much stress, however, should not be put on zonal limitations, and there may always be outbreaks of longer or shorter standing in the borders of the transition region.

HABITS AND LIFE HISTORY.

NATURE OF THE DAMAGE.

The San Jose scale, as already stated, occurs on all parts of the plant—limbs (Pl. I; Pl. VI, fig. 1), leaves, and fruit (Pl. VI, fig. 2). As the plant becomes badly infested the scales lie very close together on the limbs, frequently overlapping, sometimes with several young ones clustering over the surface of an old mature scale. The general appearance which they present is of a grayish, very slightly roughened, scurfy deposit. The natural rich reddish color of the young limbs of peach, pear, and apple is quite obscured when these trees are thickly infested, and they have then every appearance of being coated with ashes. When the scales are crusht by scraping, a yellowish, oily liquid will appear, resulting from the mashing of the soft, yellow insects beneath the scales. Examined under a hand lens during the summer, numbers of the little orange-colored larvæ will be seen running about, and the snowy white young scales will be interspersed with the old brown or blackened mature scales. The appearance presented at this time under the lens is shown in fig. 2. Very frequently the scale has a marked tendency to infest the extremities of the branches and twigs. This is particularly noticeable with pear. As usually found on peach, the scale is massed often more densely on the older growth, and works out more slowly toward the new wood.

The leaves are much less apt to bear scales, but in severe cases the upper surface particularly becomes infested, the scales frequently ranging in two or more quite regular rows on either side of the midrib.



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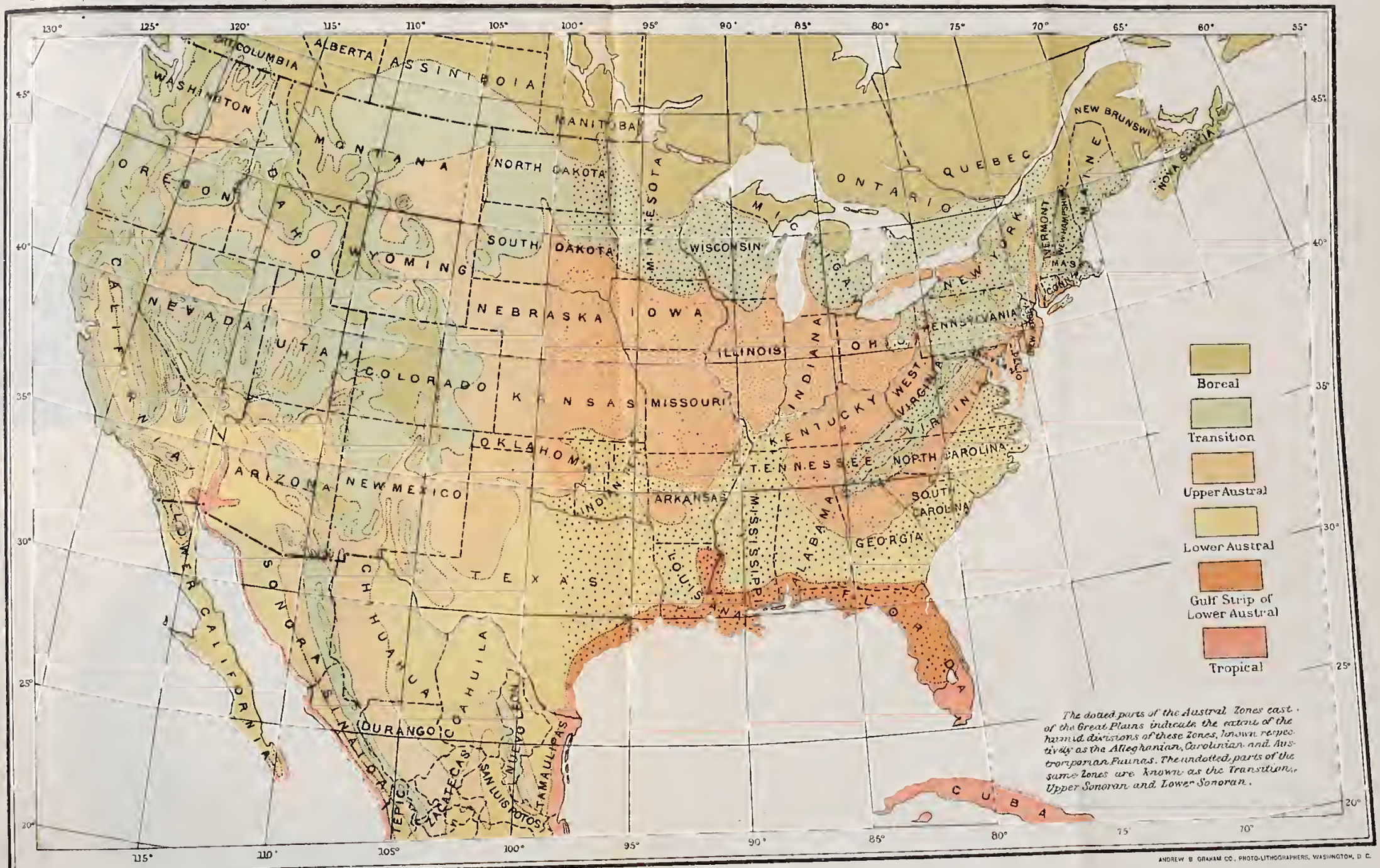

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Corrected to December, 1897

LIFE ZONES OF THE UNITED STATES

BY

C. HART MERRIAM

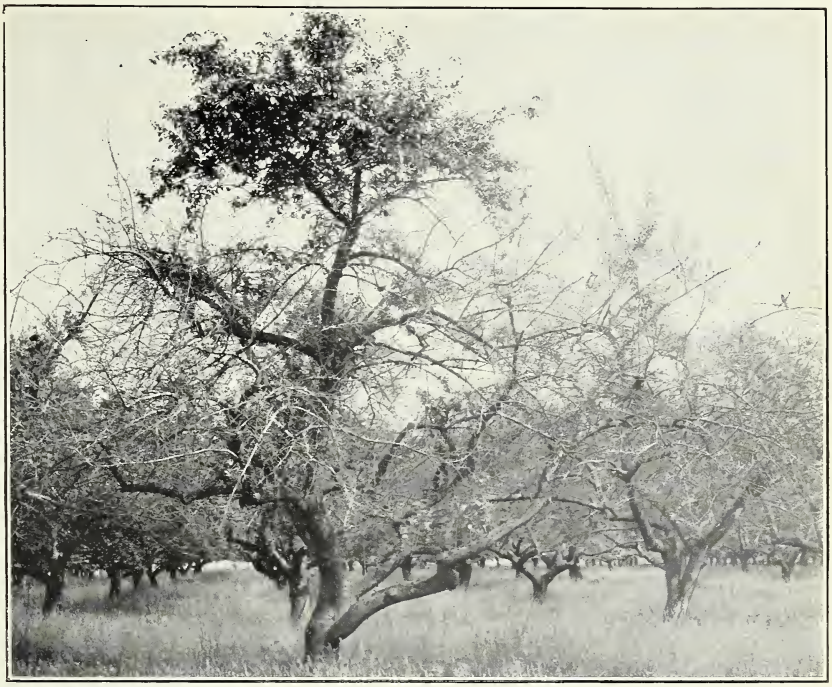


FIG. 1.—LARGE APPLE TREES WITH LOWER LIMBS KILLED BY THE SAN JOSE SCALE, YOUNGSTOWN, N. Y. (ORIGINAL.)

FIG. 2.—APPLE INFESTED WITH SAN JOSE SCALE. SLIGHTLY ENLARGED (ORIGINAL).

The male scales are more numerous on the leaves than the females. The infested leaves turn purplish brown.

The San Jose scale was formerly supposed to differ from all others in the peculiar reddening effect which it produces upon the skin of the fruit and of tender twigs. This, however, sometimes occurs with other scales, but is a particularly characteristic feature of this insect, and renders it easy to distinguish. The encircling band of reddish discoloration around the margin of each female scale is very noticeable

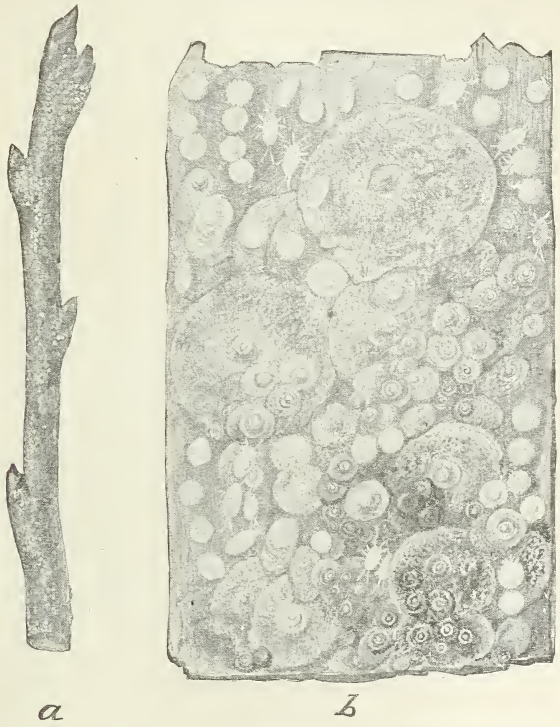


FIG. 2.—Appearance of San Jose scale (*Aspidiotus perniciosus*) on bark: *a*, infested twig, natural size; *b*, bark as it appears under hand lens, showing scales in various stages of development and young larvæ. (From Howard and Marlatt.)

on fruit, especially pears. This appearance, however, sometimes so closely resembles the small spots on fruit produced by a common fungus, *Entomosporium maculatum* Lev., as to require close examination with a lens to distinguish it. Fruit severely attacked becomes distorted, rough, and pitted, frequently cracking, and may eventually fall prematurely or at least become unmarketable.

The cambium layer of young twigs where the scales are massed together is usually stained deep red or purplish, and when the scale is only scatteringly present the distinctive purplish ring surrounding each

is almost as noticeable on young twigs as on fruit, and is of the greatest service in facilitating the inspection of trees which have been subject to possible contagion. The almost microscopic young scale might easily elude the most careful search, but the striking circling ring makes it a comparatively conspicuous object without the aid of a glass.

If the tree survives the attack the infested wood eventually becomes knotty and irregular, partly from the sapping of the juices by the insect and also without doubt largely from the poisoning of the sap of the cambium layer by the punctures of the insect, as indicated by the discoloration. Young peach trees will ordinarily survive the scale only two or three years. Pears are sometimes killed outright, but generally maintain a feeble, sickly existence, making little or no growth for a somewhat longer period.

FOOD PLANTS.

The San Jose scale may attack almost any deciduous plant, including fruits, ornamentals, and the various shade trees. Food-plant lists were published in Bulletins 3 and 12 of this Bureau, and several subsequent writers have given lists, with important additions. The most careful investigation of the subject, relating particularly to ornamental trees and shrubs, but also to fruit trees, as these are often planted for ornament, was that conducted by the State entomologist of Connecticut, Mr. W. E. Britton, who sent out a circular letter to the entomologists and horticultural inspectors of the various States asking for data under three headings, namely: (1) Plants commonly infested; (2) those occasionally or rarely infested; (3) those not infested. Forty-five replies were received, and from these and other records his list was prepared. This list I have reproduced, together with his following explanatory paragraphs.[a]

List of Hardy Trees, Shrubs, and Vines.

COMMONLY OR BADLY INFESTED.

Acacia sp. Lintner, Felt, N. Y.; Alwood, Va.
Akebia sp. Felt, N. Y.
Akebia quinata Decaisne. Alwood, Va.
Amelanchier canadensis Medic., and other species. Shad-bush, Juneberry. Britton, Koehler, Conn.; Alwood, Va.
Citrus trifoliata Linn. Scott, Ga.; Alwood, Va.; Gossard, Fla.
Cornus alba Linn. var. *sibirica* Lodd. Britton, Conn.
Cornus baileyi Coult & Evans. Gould (in N. Y.).
Cornus sanguinea Linn. Britton, Conn.
Cotoneaster sp.? Britton, Conn.; Lintner, Felt, N. Y.; Card, R. I.
Cotoneaster vulgaris Lindl. Alwood, Va.

[a] Report of the Connecticut Agricultural Experiment Station, 1902, Part II, 2d Report of the Entomologist, pp. 132–138.

Cratægus sp. Hawthorn. Britton, Conn.; Lintner, Felt, N.Y.; Alwood,Va.; Smith, N. J.

Cratægus cordata Soland. Koehler, Conn.

Cratægus oxyacantha Linn. English hawthorn. Britton, Koehler, Conn.

Cratægus coccinea Linn. Koehler, Conn.

Cratægus crus-galli Linn. Koehler, Conn.

Cydonia vulgaris Pers. Common quince. Britton, Conn.; Lintner, N. Y.; Alwood, Va.

Cydonia japonica Pers. Japanese or flowering quince. Britton, Koehler, Conn.; Lintner, N. Y.; Alwood, Va.; Johnson, Md.

Fagus sylvatica Linn. var. *purpurea* Ait. European purple-leaved beech. Smith, N. J.

Juglans sieboldiana Maxim. Japanese walnut. Britton, Conn.; Alwood, Va.; Sherman, N. C.; Smith, N. J.

Ligustrum vulgare Linn. Common privet. Alwood, Va.

Populus sp. Poplar. Britton, Conn.; Smith, N. J.; Sanderson, Del.; Felt, N. Y.

Populus deltoides Marsh. Carolina poplar. Britton, Conn.; Rolfs & Quaintance, Fla.; Alwood, Va.

Populus nigra Linn. var. *italica* Du Roi. Lombardy poplar. Britton, Koehler, Conn.; Rolfs & Quaintance, Fla.; Alwood, Va.

Prunus amygdalus Stokes. Almond. Lintner, N. Y.; Alwood, Va.

Prunus armeniaca Linn. Apricot. Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.

Prunus avium Linn. Sweet cherry. Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.; Cockerell, N. Mex.

Prunus pumila Linn. Koehler, Conn.

Prunus pumila var. *besseyi* Waugh. Sand cherry. Alwood, Va.

Prunus cerasifera Ehrh., var. *atropurpurea* Dipp. (*P. pissardi*). Purple-leaved plum. Britton, Conn.; Felt, N. Y.

Prunus domestica Linn. European plum. Britton, Conn.; Alwood, Va.

Prunus hortulana Bailey. Wild goose plum. Alwood, Va.

Prunus japonica Thunb. Flowering almond. Britton, Conn.; Felt, N. Y.

Prunus maritima Waugh. Beach plum. Koehler, Britton, Conn.

Prunus persica Sieb. & Zucc. Peach. Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Cockerell, N. Mex.

Prunus triflora Roxbg. Japanese plum. Britton, Koehler, Conn.; Alwood, Va.

Prunus serotina Ehrh. Koehler, Conn.

Prunus virginiana Linn. Chokecherry. Koehler, Conn.

Ptelea trifoliata Linn. Hop tree. Fernald, Mass.

Pyrus communis Linn. Pear. Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Cockerell, N. Mex.

Pyrus sinensis Lindl. Sand pear, including Kieffer. Alwood, Va.

Pyrus baccata Linn. Koehler, Conn.

Pyrus malus Linn. Apple. Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Doten, Nev.; Cockerell, N. Mex.

Pyrus sp. Crab apple. Britton, Conn.

Ribes oxyacanthoides Linn. Gooseberry. Britton, Conn.: Lintner, Felt, N. Y.; Alwood, Va.; Troop, Ind.

Ribes aureum Pursh. Missouri or flowering currant. Lintner, N. Y.

Ribes rubrum Linn. Currant. Britton, Conn.; Lintner, Felt, N. Y.

Ribes nigrum Linn. Black currant. Alwood, Va.

Rosa sp. Britton, Conn.; Lintner, N. Y.; Alwood, Va.; Cockerell, N. Mex.; Burgess, Ohio; Troop, Ind.; Gould, Md.; Scott, Ga.

Rosa carolina Linn. Koehler, Conn.

Rosa lucida Ehrh. Koehler, Conn.

Rosa virginiana Mill. Koehler, Conn.
Rosa rugosa Thunb. Britton, Koehler, Conn.
Salix sp. Willow. Britton, Conn.; Felt, N. Y.; Sanderson, Del.
Salix lucida Muhl. Koehler, Conn.
Salix pentandra Linn. Laurel-leaved willow. Lintner, N. Y.; Alwood, Va.
Salix vitellina Linn. Koehler, Conn.
Salix babylonica Linn. Weeping willow. Lintner, N. Y.; Alwood, Va
Salix humilis Marsh. Koehler, Conn.
Salix incana Schrank. Koehler, Conn.
Sorbus sp. Mountain ash. Felt, N. Y.; Hunter, Kans.
Sorbus americana Marsh. American mountain ash. Britton, Koehler, Conn.; Alwood, Va.
Sorbus aucuparia Linn. European mountain ash. Britton, Koehler, Conn.
Sorbus melanocarpa C. Koch. (*Aronia nigra* Koehne). Black chokeberry. Koehler, Conn.
Symphoricarpos racemosus Michx. Snowberry. Felt, N. Y.; Smith, N. J.
Syringa vulgaris Linn. Common lilac. Burgess, Ohio; commissioner of agriculture, N. Y.; Troop, Ind.; Alwood, Va.
Syringa persica Linn. Persian lilac. Britton, Conn.
Tilia sp. Basswood, linden. Britton, Conn.; Lintner, commissioner of agriculture, N. Y.
Tilia americana Linn. American linden or basswood. Britton, Conn.; Alwood, Va.
Toxylon pomiferum Raf. Osage orange. Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.
Ulmus sp. Elm. Lintner, N. Y.; Webster, Ohio; Troop, Ind.
Ulmus americana Linn. American elm. Britton, Koehler, Conn.; Alwood, Va.
Ulmus campestris Smith. English or European elm. Britton, Conn.; Felt, N. Y.; Smith, N. J.

OCCASIONALLY OR RARELY INFESTED.

Acer sp. Maple. Webster, Burgess, Ohio; Fernald, Mass.; Butz, Pa.; commissioner of agriculture, N. Y.
Acer saccharinum Linn. Silver maple. Gould, Md.; Alwood, Va.; Hunter, Kans.; Felt, N. Y.
Acer saccharinum. Weir's cut-leaved. Felt, N. Y.
Acer platanoides Linn. Norway maple. Gould, Md.
Actinidia arguta Miq. (*A. polygama*). Alwood, Va.
Æsculus hippocastanum Linn. Horse-chestnut. Felt, commissioner of agriculture, N. Y.; Burgess, Parrot, Green, Ohio.
Alnus sp. Alder. Felt, N. Y.; Alwood, Va.
Ampelopsis quinquefolia Michx. Virginia creeper. Alwood, Va.
Betula sp. Birch. Felt, N. Y.
Betula alba Linn. Cut-leaved white birch. Britton, Conn.; Rolfs & Quaintance, Fla.
Buxus sp. Box. Britton, Conn.
Castanea americana Raf. Chestnut. Rolfs & Quaintance, Fla.; Alwood, Va. Felt, N. Y.
Catalpa sp. Rolfs & Quaintance, Fla.
Catalpa bignonioides Walt. Common catalpa. Alwood, Va.
Ceanothus americanus Linn. Koehler, Conn.
Celtis occidentalis Linn. Koehler, Conn.
Cercidiphyllum japonicum Sieb. & Zucc. Britton, Conn.
Citrus aurantium Linn. Gossard, Fla.
Cornus alternifolia Linn. Koehler, Conn.
Cornus stolonifera Michx. Koehler, Conn.

Cornus circinata L'Hérit. Koehler, Conn.
Cornus amomum Mill. Koehler, Conn.
Cornus candidissima Marsh. Koehler, Conn.
Cornus florida Linn. Commissioner of agriculture, Felt, N. Y.; Britton, Conn.
Cornus florida. Red flowering. Alwood, Va.
Deutzia sp. Fernald, Mass.
Diospyros virginiana Linn. Persimmon. Lintner, N. Y.
Elæagnus sp. Felt, N. Y.
Elæagnus longipes Gray. Silver thorn. Commissioner of agriculture, N. Y.; Scott, Ga.
Eucalyptus sp. Felt, N. Y.
Euonymus sp. Lintner, N. Y.; Alwood, Va.
Ficus carica Linn. Fig. Felt, N. Y.
Forsythia sp. Commissioner of agriculture, N. Y.
Fraxinus sp. Ash. Felt, N. Y.; Butz, Pa.
Fraxinus americana Linn. White ash. Hunter, Kans.
Gleditschia triacanthos Linn. Honey locust. Britton, Conn.; Sanderson, Del.; commissioner of agriculture, N. Y.; Johnson, Md.
Hibiscus syriacus Linn. Shrubby althea. Smith, N. J.
Hicoria pecan Britt. Pecan nut. Lintner, N. Y.; Alwood, Va.; Scott, Ga.
Juglans nigra Linn. Black walnut. Alwood, Va.; Rolfs & Quaintance, Fla.
Juglans regia Linn. Persian or English walnut. Alwood, Va.; Lintner, Felt, N. Y.; Sanderson, Md.
Kalmia latifolia Linn. Mountain laurel. Felt, N. Y.
Kerria japonica DC. Globe flower. Japanese rose. Felt, N. Y.
Ligustrum ovalifolium Hassk. California privet. Britton, Koehler, Conn.
Lonicera sp. Honeysuckle. Felt, N. Y.
Morus sp. Mulberry. Alwood, Va.; Burgess, Ohio; Johnson, Md.; Scott, Ga.
Morus sp. Tea's weeping mulberry. Taft, Mich.
Physocarpus opulifolius Maxim. Koehler, Conn.
Picea alba Link. White spruce. Fernald, Mass.
Prunus cerasus Linn. Sour cherry. Felt, N. Y.; Alwood, Va.; Burgess, Ohio.
Photinia villosa DC. Koehler, Conn.
Rhodotypos kerrioides Sieb. & Zucc. Koehler, Conn.
Rhus sp. Sumac. Rolfs & Quaintance, Fla.; Alwood, Va.; Felt, N. Y.
Rhus cotinus Linn. Smoke bush. Commissioner of agriculture, N. Y.
Robinia sp. Locust. Sanderson, Del.; Burgess, Webster, Ohio; Johnson, Md.
Rubus strigosus Michx. Red raspberry. Alwood, Va.; Lintner, Felt, N. Y.; Johnson, Md.
Rubus nigrobaccus Bailey (*R. villosus*). Common blackberry. Lintner, Felt, N. Y.; Johnson, Md.
Rubus villosus Ait. (*R. Canadensis*). Dewberry. Felt, N. Y.
Sambucus sp. Elder. Commissioner of agriculture, N. Y.; Fernald, Mass.; Webster, Ohio.
Sassafras officinale Nees. Sassafras. Sanderson, Del.
Sorbaria sorbifolia A. Braun (*Spiræa sorbifolia* L.). Britton, Conn.
Spiræa sp. Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.
Thuya occidentalis Linn. Arborvitæ. Fernald, Mass.
Viburnum sp. Britton, Conn.; Alwood, Va.
Viburnum cassinoides Linn. Britton, Koehler, Conn.
Viburnum opulus Linn. Koehler, Conn.
Vitis sp. Grapes. Britton, Conn.; Felt, N. Y.; Alwood, Va.; Butz, Pa.; Rolfs & Quaintance, Fla.; Johnson, Md.

NOT INFESTED.

Ailanthus glandulosa Desf. Tree of heaven.
Amorpha fruticosa Linn.
Andromeda sp.
Aralia spinosa Linn. Hercules' club.
Aristolochia macrophylla Lam. Dutchman's pipe.
Asimina triloba Dun. Papaw.
Baccharis halimifolia Linn. Groundsel tree.
Benzoin odoriferum Nees. (*Lindera benzoin* Blume). Spicebush.
Berberis (all species). Barberry, including *Mahonia*.
Bignonia sp. Trumpet vine.
Calycanthus floridus Linn. Carolina allspice, sweet-scented shrub.
Carpinus sp. Hornbeam.
Cedrus sp. Cedar.
Celastrus scandens Linn. Bittersweet.
Cephalanthus occidentalis Linn. Buttonbush.
Cercis canadensis Linn. Judas tree, redbud.
Chamædaphne calyculata Mœnch. (*Cassandra*). Leather leaf.
Chionanthus virginica Linn. Fringe tree.
Cladrastis tinctoria Raf. Yellowwood.
Clethra alnifolia Linn. Sweet pepper bush.
Corylus sp. Filbert, hazelnut.
Daphne mezereum Linn.
Diervilla sp. Weigela.
Dirca palustris Linn. Leatherwood, moosewood.
Exochorda grandiflora Lindl. Pearlbush.
Gaylussacia sp. Huckleberry.
Genista tinctoria Linn. Dyer's greenweed.
Ginkgo biloba Linn. Maidenhair tree.
Gymnocladus canadensis Lam. Kentucky coffee tree.
Halesia tetraptera Linn. Silver bell, snowdrop tree.
Hamamelis virginiana Linn. Witch hazel.
Hedera helix Linn. English ivy.
Hicoria sp. (excepting *H. pecan* Britt). Hickory.
Hydrangea (all species).
Hypericum moserianum André. Gold flower.
Ilex sp.
Itea virginica Linn. Virginian willow.
Jasminum nudiflorum Lindl. Yellow jasmine.
Juglans cinerea Linn. Butternut.
Juniperus sp. Juniper.
Kalreuteria paniculata Laxm. Varnish tree.
Laburnum vulgare Griseb. Golden chain.
Larix sp. Larch.
Liquidambar styraciflua Linn. Sweet gum.
Liriodendron tulipifera Linn. Tulip tree.
Lycium halimifolium Mill. Matrimony vine.
Magnolia (all species).
Myrica cerifera Linn. Wax myrtle.
Nyssa sylvatica Marsh. Tupelo, pepperidge, black gum, sour gum.
Ostrya virginica Willd. Hornbeam, iron wood.
Paulownia imperialis Sieb. & Zucc.

Phellodendron sp.
Philadelphus coronarius Linn. Mock orange, syringa.
Pinus sp. Pine.
Platanus occidentalis Linn. American plane, buttonwood.
Potentilla fruticosa Linn.
Quercus (all species). Oak.
Retinispora (all species). Japan cypress.
Rhamnus sp. Buckthorn.
Rhododendron sp.
Sciadopitys verticillata Sieb. & Zucc. Umbrella pine.
Shepherdia sp.
Smilax sp.
Sophora japonica Linn. Japan pagoda tree.
Staphylea sp. Bladder nut.
Stephanandra flexuosa Sieb. & Zucc.
Styrax japonica Sieb. & Zucc.
Tamarix sp.
Taxodium distichum Rich. Bald cypress.
Taxus sp. Yew.
Tecoma radicans Juss. Trumpet creeper.
Tsuga canadensis Carr. Common hemlock.
Vaccinium sp.
Wistaria sp.
Xanthoceras sorbifolia Bunge.
Xanthoxylum americanum Mill. Prickly ash.

Certain species have been reported as seriously infested in one part of the country and as exempt in other localities. Such plants have been placed in list No. 1. Quince is reported as being rarely infested, by Felt, of New York, and by Smith, of New Jersey. Sanderson writes that willows and poplars are not commonly infested in Maryland and Delaware, but in Connecticut willow hedges have been seriously infested, and young willow and poplar trees in nurseries have been thoroly incrusted by the scales. Cockerell reports that osage orange is not infested in New Mexico tho much grown, and that *Catalpa*, elm, and walnut have not been found infested. Apricot, quince, and poplar are also reported as not being infested in New Mexico. Alwood, of Virginia, Burgess, of Ohio, and Felt, of New York, place the sour cherry (*P. cerasus*) in list No. 2, tho I have never found it infested in Connecticut. Burgess suggests that Kieffer pear be placed in the same list, but it is reported by Alwood as being badly infested in Virginia. Linden was placed in list No. 1 by the commissioner of agriculture of New York, while the hop-tree (*Ptelea trifoliata*) was placed in the same list by Fernald of Massachusetts. Elm was placed in list No. 1 by Webster in Ohio and Troop of Indiana. Smith, of New Jersey, finds European elm, purple-leaved beech, and Japanese walnut badly infested, while the common quince, cherry (except on Japanese stock), apricot, and poplar are not commonly infested. He has not seen the scale on birch, linden, persimmon, *Catalpa*, *Acacia*, or *Buxus*. Alwood, of Virginia, puts the common privet (*L. vulgare*) in list No. 1, while Koehler, in Connecticut, mentions it as one of the plants upon which he has not found the scale, tho growing near infested plants. Gossard, of Florida; Scott and Fiske, of Georgia, report *Citrus trifoliata* as being badly infested, while Alwood, of Virginia, places this plant in list No. 2. *C. aurantium* the common orange, is rarely infested, according to Gossard.

In Connecticut the most commonly infested plants are apple, pear, peach, Japan plum, and currant among the fruits, tho sweet cherry, European plum, quince, and gooseberry are sometimes seriously injured.

The most commonly infested ornamentals are purple-leaved plum, *Cratægus*, Japanese quince, mountain ash, red-twigged dogwood, and *Rosa rugosa*. Poplar, willow, Persian lilac, *Cotoneaster*, elm (both American and European), and osage orange have been found thoroly incrusted by the insects, especially when growing near infested trees.

Of the plants which are reported as noninfested in this list probably many of them may be subject to slight or occasional infestation. Notwithstanding the San Jose scale's wide range of food plants, strangely enough certain varieties of pear seem to be almost never attacked, and are practically exempt from injury. This holds true also, to a less extent, with different varieties of other fruits. The striking illustrations are the Leconte and Kieffer varieties of pears, and the reason for this immunity is difficult to explain. Differences in the density and texture of bark could hardly account for it, because that would scarcely protect new and comparatively tender growth. A notable instance of the immunity of the Leconte pear is seen in the little grove connected with the insectary of this Department. This grove has been thickly planted to pear and apple trees, so that the branches are interlacing all the time, and it has been pretty badly infested with the San Jose scale off and on for ten years, and yet the 10 or 12 Leconte trees have been clean the whole time, while the rest, representing different varieties of pear, apple, peach, and plum, have died out or have been replaced, some of them over and over again.

CITRUS FRUITS AND THE SAN JOSE SCALE.

The susceptibility of the orange and lemon and other citrus plants to the San Jose scale is a matter of great interest to citrus growers. In catalogs of the food plants of the San Jose scale the orange and lemon and other citrus fruits are listed, notably in Mrs. Fernald's Catalog of Coccidæ. The facts on which this statement is based are rather meager, and, when examined, do not warrant any grave fears of injury to the ordinary cultivated citrus fruits. It is well known that the San Jose scale will infest rather freely the trifoliate orange, a hedge plant somewhat closely related to the orange and lemon. Some trifoliate trees, for example, on the Department grounds, are now rather thickly covered by the San Jose scale, but even in the case of this hedge plant the infestation is, as a rule, not serious, and, according to Mr. Gossard, the plant seems to throw the scale off as it grows. The first undoubted example of San Jose scale on orange was on certain hybrid sorts produced by crossing the trifoliate orange with the sweet orange, and was received in 1903 from Mr. Gossard from Florida. Mr. Gossard stated that in a single instance where a small sweet orange tree interlaced with the branches of a badly infested trifoliate orange the former had matured perhaps half a dozen San Jose scales.

The second undoubted record is of material sent to Doctor Howard for determination by Dr. James Fletcher, entomologist of the Canadian Central Experimental Farm at Ottawa, who reported that the infested oranges sent had been forwarded to him from British Columbia and had been imported from Japan. These oranges, evidently of a mandarin or tangerine type, showed undoubted infestation with the San Jose scale. It is therefore evident that this scale insect may occasionally infest the orange, but the long coexistence of the San Jose scale and orange culture in southern California would seem to indicate the practical immunity of the orange tree from this scale pest. An earlier record of the San Jose scale on a citrus plant, by Mr. Cockerell, has always been under the question of a misidentification of the food plant.

LIFE HISTORY.

In common with all the armored scales, the life round of this insect, with the exception of a few hours of active larval existence and an equally brief winged existence in the case of the mature male, is past under the protection of a waxy scale. This scale covering conceals the real insect beneath and prevents any easy observation or study of its life history. The San Jose scale has been under most careful observation by Mr. Pergande on potted plants in the insectary, and its history, which has hitherto been very imperfectly worked out, has been thoroly and carefully elaborated.

The winter is past by the insects in a half-grown condition under small black protecting scales, mere points, just visible to the naked eye. The male scales are normally vastly in excess of the females, often representing 95 or more per cent. Early in April, in this latitude, the males transform to pupæ and emerge, and this gives the appearance of a sudden death of the great majority of these overwintered insects on the bark, and has led to some confusion in interpreting the effect of washes. The females at this period have arrived at the stage of impregnation, and the delicate two-winged males disappear after a few days. About a month later, varying with the climate, the overwintered females come to full maturity and begin to give birth to a new generation, continuing to produce young for a period of upward of six weeks, when they reach the limit of production of young and perish.

The adult female gives birth immediately to living young, differing in this respect from most other scale insects. Ordinarily eggs are deposited beneath the scale, which in the course of a longer or shorter time hatch, and the young larvæ make their escape and migrate to different parts of the plant. In the case of some scale insects the female fills its scale with eggs in the fall and perishes, the eggs wintering over and hatching the following spring. In others the insect

hibernates in the nearly mature condition, as does the San Jose scale, and deposits eggs in the spring or early summer. The viviparous habit, or the giving birth to the living young, possest by the San Jose scale, finds a parallel in many other insects and frequently in aphides. In the case of the San Jose scale the eggs are fairly well formed, a few at a time, within the body of the mother. What takes the place of the eggshell consists of a very delicate and thin membrane—the amnion—which incloses the developing larva and which at the moment of birth is cast off, and remains attached to or partly within the oviduct. The amnion is probably pushed out by the next larva in turn.

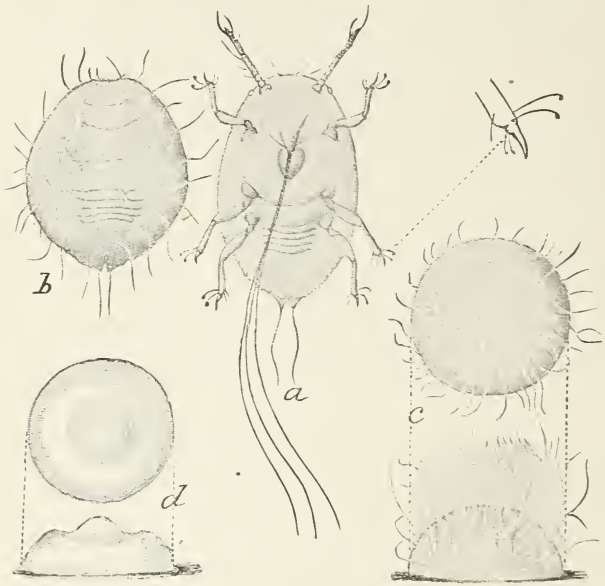


FIG. 3.—Young larva and developing San Jose scale (*Aspidiotus perniciosus*): *a*, ventral view of larva, showing sucking beak with setæ separated, with enlarged tarsal claw at right; *b*, dorsal view of same, still more contracted, with the first waxy filaments appearing; *c*, dorsal and lateral views of same, somewhat contracted, illustrating further development of wax secretion; *d*, later stage of same, dorsal and lateral views, showing matting of wax secretions and first form of young scale. All greatly enlarged (from Howard and Marlatt).

The difference between this mode of birth and the ordinary method thru the medium of true eggs is simply that what corresponds with the egg is retained by the female until the larva is developed, instead of development of the larva progressing after the egg leaves the parent.

The emergence of the young from the female over a period of six weeks leads to a very confusing intermingling of generations and renders it difficult to make observations on the life history except by isolating and watching individuals. By means of such isolation of individuals, however, we have been able to most carefully trace the

different generations. The course of the development of a single generation follows:

After being expelled the larva remains motionless for a little while, with antennæ and legs folded beneath the body. It soon hardens enough to run about, and, forcing its way out from beneath the protecting scale of the mother, scurries over the plant to find a suitable place to settle.

The newly born larva (fig. 3, *a*) is an almost microscopic creature of pale orange-yellow color, with long oval body, and with the customary six legs and two feelers. The long thread-like proboscis with which the juices of the plant are sucked up is doubled on itself and lies in an invagination of the body wall, the tip only projecting.

After crawling about for a few hours the young larva settles down and slowly works its long bristle-like sucking beak thru the bark, folds its antennæ and legs beneath its body, and contracts to a nearly circular form. The development of the scale begins even before the larva becomes fixt. The secretion starts in the form of very minute white fibrous waxy filaments, which spring from all parts of the body and rapidly become more numerous and dense (fig. 3, *b*, *c*). At first the orange color of the larva shows thru the thickening downy white envelop, but within two days the insect becomes entirely concealed by the white or pale grayish yellow shell or scale, which now has a prominent central nipple (fig. 3, *d*), the younger ones often possessing instead a central tuft. The scale is formed by the slow matting and melting together of the filaments of wax. During the first day the scale appears like a very microscopic downy hemisphere. The matting of the secretion continues until the appearance of down and individual filaments is entirely lost and the surface becomes smooth. In the early history of the scale it maintains its pale whitish or grayish yellow color, turning gradually darker gray, the central nipple remaining lighter colored usually thruout development.

The male and female scales are exactly similar in size, color, and shape until after the first molt, which occurs twelve days after the emergence of the larva. With this molt, however, the insects beneath the scale lose all resemblance to each other. The males (fig. 4, *a*) are rather larger than the females and have large purple eyes, while the females have lost their eyes entirely. The legs and antennæ have disappeared in both sexes. The males are elongate and pyriform, while the females are almost circular, amounting practically to a flattened sac with indistinct segmentation, and without organs, except a long sucking bristle springing from near the center beneath. The color of both sexes is light lemon-yellow. The scales at this time have a decidedly grayish tint, overcast somewhat with yellow.

Eighteen days from birth the males change to the first pupal condition (pro-pupa) (fig. 4, *b*), and the male scales assume an elongate oval,

sometimes slightly curved, shape, characteristic of the sex, the exuvia or cast larval skin showing near the anterior end.

The male pro-pupæ are very pale yellow, with the legs and antennæ (which have reappeared), together with the two or three terminal segments, colorless. The eyes are dark purple and placed close together. The antennæ are stout and bent closely along the edge of the body as far as the first pair of legs, where they curve slightly inward. Prominent wing pads extend along the sides of the body. The terminal segment bears two short spines.

The female undegroes a second molt about twenty days from the larva. At each molt the old skin splits around the edge of the body, the upper half adhering to the covering scale and the lower forming a sort of ventral scale next to the bark. This form of molting is common to scales of this kind.

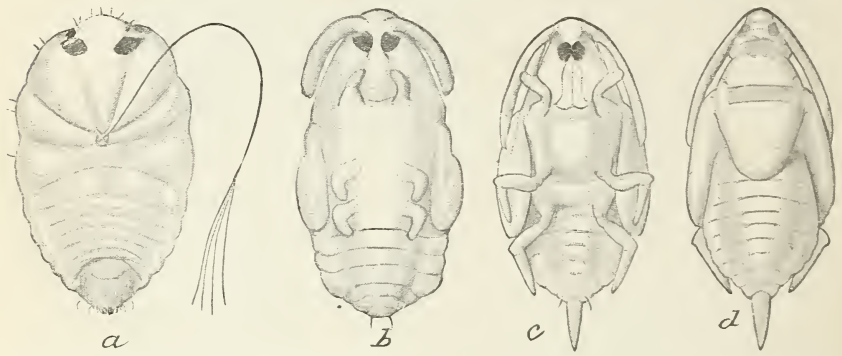


FIG. 4.—Development of male San Jose scale (*Aspidiotus perniciosus*): *a*, ventral view of larva after first molt; *b*, same after second molt (pro-pupa stage); *c* and *d*, true pupa, ventral and dorsal views. All greatly enlarged (from Howard and Marlatt).

The covering scales at this stage are of a more purplish gray, the portion covering the exuviæ inclining to yellowish. The male scales are more yellowish than the female. The effect of the sucking of the insects is now quite apparent on the young growth, causing the bark to assume a purplish hue for some distance around the central portion, contrasting strongly with the natural reddish green of the uninjured bark. With the second molt the females do not change materially from their former appearance, retaining the pale yellow color with a number of transparent spots around the edge of the body. The sucking bristles are extremely long, two or three times the length of the body of the insect. The only distinctive features are in the last segment and are noted in the technical description.

About twenty days after birth the male insect transforms to the true pupa. With the first molt the shed larval skin is retained beneath the scale as in the case of the female; with the later moltings the shed skins are pushed out from beneath the scale. The scale after the

second molt presents on the inside two longitudinal ridges running from one end to the other, touching the sides of the pupa, and which apparently enable the insect to move backward or forward and assist the imago in pushing itself out.

The true pupa (fig. 4, *c*, *d*) is pale yellow, sometimes purplish, darkest about the base of the abdomen. The head, antennæ, legs, wing pads, and style are well formed, but almost colorless. The antennæ reach as far back as the second pair of legs and are not curved under, as formerly, but lie close to the sides of the body with the ends free. The first pair of legs is held forward, reaching slightly beyond the eyes, the middle femora projecting somewhat beyond the margin of the abdomen. The hind legs are inclined backward and reach to the end of the body. The style is rounded at tip, conical, and about as long as the posterior tibiæ.

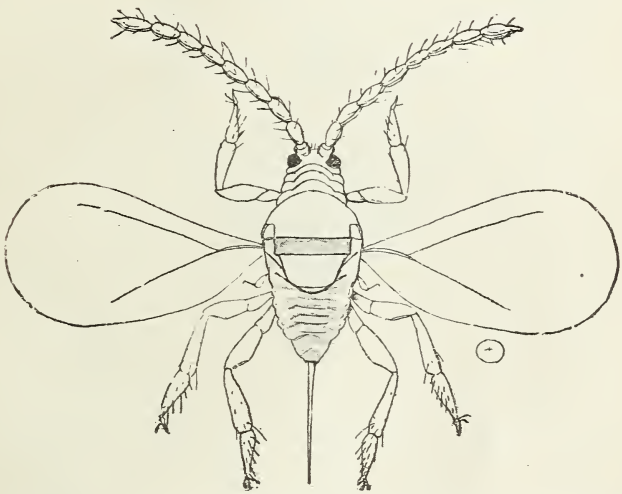


FIG. 5.—*Aspidiotus perniciosus:* adult male, greatly enlarged (from Howard and Marlatt).

From four to six days later, or from twenty-four to twenty-six days from birth, the males mature and back out from the rear end of their scales, having previously, for a day or two, remained practically developed but resting under the scale. They seem to issue chiefly by night or in the evening.

The mature male (fig. 5) appears as a delicate two-winged fly-like insect with long feelers and a single anal style projecting from the end of the body; orange in color, with a faintly dusky shade on the prothorax. The head is darker than the rest of the body, the eyes are dark purple, and the antennæ, legs, and style are smoky. The wings are iridescent with yellow and green, very faintly clouded.

Thirty days from birth the females are full grown and the embryonic young may be seen within their bodies, each inclosed in a delicate

membrane. At from thirty-three to forty days the larvæ again begin to make their appearance.

The adult female, prior to the development of the young, measures 1 millimeter in length and a little less in breadth, and is pale yellow, with transparent spots near the margin of the body (fig. 6).

The length of a generation is determined by the female and, as shown by the above record, covers a period of from thirty-three to forty days. Successive generations were followed carefully thruout

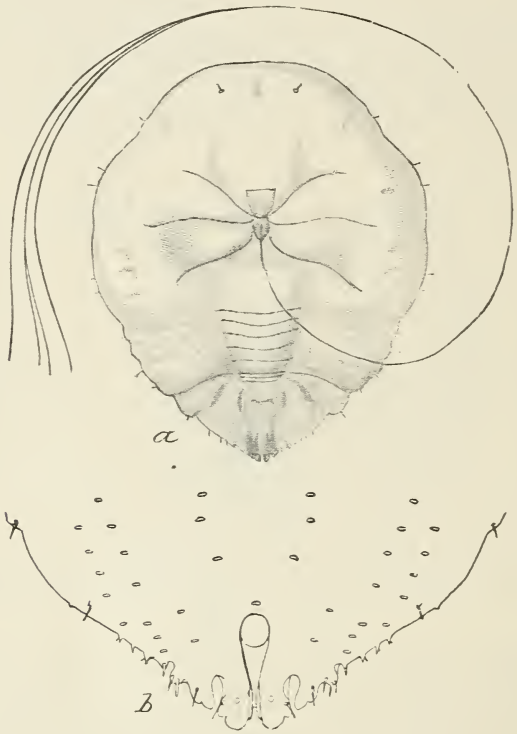


FIG. 6.—Adult female San Jose scale (*Aspidiotus perniciosus*) before development of eggs: *a*, ventral view, showing very long sucking setæ; *b*, anal plate, showing characteristic ornamentation of edge. Greatly enlarged (from Howard and Marlatt).

the summer, and it was found that at Washington four full generations are regularly developed, with the possibility of a partial fifth generation. On a number of potted trees a single overwintered female was left to each tree. After the full progeny of this individual had gone out over the tree, all were removed again, except one of the oldest and fertilized females. This method was continued for each generation thruout the breeding season. Some interesting records, tabulated below, were thus obtained, which indicate the fecundity of the females as well as the number of generations.

Record showing fecundity of San Jose scale.

Number of tree.	Males.	Females.	Total.
	Progeny of overwintered females.		
1	72	34	106
2	77	43	120
3	138	60	198
4	18	22	40
5	98	60	158
6	33	25	58
7	13		13
	Progeny of second generation.		
1	350	235	585
2	276	226	502
3	325	92	417
4	192	120	312
5	415	151	556
	206	124	330

Number of tree.	Males.	Females.	Total.
	Progeny of third generation.		
1	110	307	417
2	122	464	586
3	190	284	474
4	187	400	587
5	174	280	454
6	107	274	354
	Progeny of fourth generation.		
1	242	319	561
2	112	230	342
3	92	170	262
4	210	344	554
5	242	343	585
6	156	293	449

Perhaps the most notable feature of the foregoing records is the result obtained from the overwintered females. It will be seen that the males greatly predominate in this generation, and that the numbers of both sexes are insignificant compared with the progeny of the later generations. The males still predominate in the second generation, but in the third and fourth generations the females considerably outnumber the males, in one instance the females from a single mother reaching the astonishing number of 464, which, with 122 males from the same parent, makes the progeny of this female 586 insects. Taking 200 females as an average of the different generations for the year, the product of a single individual from spring to fall amounts to 1,608,040,200 females. In one instance we have over 415 males from a single female, and while the number of males would average somewhat less than the females, taking the summer thru, yet, having underestimated the females, the males may be estimated at the same number, giving a total of 3,216,080,400 descendants from a single insect in a single season. It is not to be expected, of course, that all the individuals from a scale survive and perform their function in life, but under favorable conditions, or in the case of a tree newly infested or not heavily incrusted, the vast majority undoubtedly go thru their existence without accident. Neither the rapidity with which trees become infested nor the fatal effect which so early follows the appearance of this scale insect is therefore to be wondered at.

Owing to the long period during which the female is continuously producing young the different generations or broods in the course of the summer are not distinctly marked and merge insensibly into each other—so much so that at almost any time there will be found young larvæ running about over the trees and scales in all stages of development. Still, at certain times the young will be noticeably more abundant, indicating periods when the majority of each generation are producing young. In this latitude the first young appear, as noted, by the middle

of May; at Amherst, Mass., they were first noticed June 12, and in Arizona they are recorded as appearing in March. The larvæ are continuously present on the trees until further hatching is prevented by severe frosts. In 1894, as we have already shown on page 289 of Volume VII of Insect Life, the first frosts at Washington occurred in the latter part of October and the hatching of the young ceased before the 1st of November. October 24, 1894, however, Doctor Howard saw recently settled larvæ, not more than 5 days old, at Lewisburg, Pa. In 1895 the October frosts were insignificant, and in this neighborhood no severe frost occurred until about the 1st of December. The result was that young larvæ were found at Washington until late in November, while on twigs received from Chestertown, Md., November 13 and November 27, the young were more or less abundant. The cold spell of the last week in November and the first week in December put a stop to development here. This same cold spell was of very wide extent. As far to the southwest as San Antonio, Tex., the thermometer dropped to 31° on December 3. A similar, or even lower, temperature was noted at New Orleans, yet on December 16 Doctor Howard found newly hatched young, less than 24 hours old, upon a plum tree at Audubon Park, New Orleans.

In autumn, or when further development is stopt by cold weather, hibernation is begun by scales in all stages of development, from the white, minute, down-covered recently hatched young to the mature and full-grown females and males. Unquestionably many young perish during the winter, and normally in spring quite a percentage of the smaller or half-grown scales will be found to have perished. It is very probable that many females have union with the males in the fall, but the majority of them are unquestionably immature, and are fertilized in this latitude early in April by overwintered males which, as we have noted, appear nearly a month before the first young of the spring brood.

The actual rate of the production of young at different periods of the life of the adult female has not been determined with accuracy. As the average reproducing period of the adult female is six weeks, and as the average number of young from each female is about 400, there must be born from 9 to 10 young every twenty-four hours. The great labor of watching an individual female and removing every twenty-four hours the young she has given birth to during that period has not been entered upon. Sufficient observations have been made, however, to indicate that the main period of reproductive activity is the second or third week after the female has reached maturity. At first the young are born with less frequency, and there is a corresponding reduction in reproductive activity toward the end of the life of the individual. The young are born indifferently by day or by night, perhaps more during the day than during the night. In the morning,

however, examination of the trees under observation always shows many migrating young which must have been born during the night, while observations at nightfall show always as many, and frequently more, which have been born during the day.

The gradual production of the young by the female has an important bearing on the question of remedies, and the old washes, which aimed at the destruction of the young as soon as they emerge from the females, are rendered almost valueless because, to make them effective, it is necessary to repeat them many times during a period of six weeks. Within two or three days after hatching the young larvæ will have formed a scale which will be impervious to these weaker washes.

The larva does not ordinarily travel far from the parent insect, and usually rests within a few inches of the old scale or at the first available point. They will not, so far as observed, travel very far from the base of the tree, and in the potted trees none were observed to go more than 2 inches from the base of the trunk.

DESCRIPTIONS OF SCALE AND INSECT.

Scale of female.—The scale of the female is circular, very slightly raised centrally, and varies in diameter from 1 to 2^{mm}, averaging about 1.4^{mm}. The exuvia is central or nearly so. The large, well-developed scales are gray, excepting the central part covering the exuvia, which varies from pale to reddish yellow, altho in some cases dark colored. The scale is usually smooth exteriorly or sometimes slightly annulated, and the limits of the larval scale are always plainly marked. The natural color of the scale is frequently obscured by the presence of the sooty fungus (*Fumago salicina*).

Scale of male.—The mature male scale is oblong-oval, nearly twice as long as wide, and averaging in length about half the diameter of the female scale. The position of the larval scale is marked by a nipple-like prominence located between the center and the anterior margin of the scale. The scale of the male is usually darker than that of the female, sometimes black, but often gray, the larval scale covering the exuvia very frequently light yellow, as with the female. Not uncommonly the circular scale, formed prior to the first molt, is black, while the later additions, giving it its oblong shape, are gray.

The scale covering of the hibernating insects in winter is black, and on the bark in summer also the scale covering is dark or often blackened by the sooty fungus referred to. But the normal color of the scale of both female and male is light, and on the leaves of pear, for example, the male scales are often a very light buff, and present such a marked contrast to the winter appearance that no one would suspect them of belonging to the same insect.

Egg.—The egg is never (or rarely) extruded as such by the female, and as it exists within the body of the mother is a mere amniotic mem-

brane, and the forming embryo showing through gives it a yellowish-white color. The embryo with the envelop measures about 0.2^{mm} long by 0.1^{mm} wide.

Newly hatched larva.—The young larvæ of both sexes are alike, and are pale orange in color, with long oval bodies. They measure in length about 0.24^{mm} by 0.1^{mm} in width. The sucking bristles are normally doubled on themselves, but when unfolded are nearly three times the length of the body. The antennæ are apparently five-jointed, the last two joints being much longer than the others, slender, subequal in length, and both finely and distinctly annulated. The last joint bears a small nipple-like projection near the tip. The head is somewhat concave in front, and the eyes are nearly transparent and slightly purplish. The terminal segment of the abdomen foreshadows in structure the plates and spines of the adult female. The large central plates each terminate in a long hair. The tarsus is represented by apparently a single, strong, slightly curved claw. The tip of the tibia bears exteriorly two rather long capitate hairs, and two similar hairs project also from the inner extremity. Other details of structure are shown in the illustration.

Larva of the second stage.—After the first molt the difference in the sexes becomes apparent, altho the covering scales are still identical.

The female insects are somewhat smaller than the males at this stage. The eyes, legs, and antennæ in this sex have entirely disappeared. The form is almost circular, flattened. The color is yellow, with irregular transparent spots appearing in different parts of the body.

The males are somewhat larger than the females, elongate, pyriform. The eyes are prominent, purple in color. The legs and antennæ, as with the females, are wanting. The general color of the body is yellow, with the irregular transparent spots noted in the case of the female. The greatest diameter in both sexes is less than one-half a millimeter, and in the characteristics of the terminal segment both agree, practically, with the adult female.

Male pro-pupa.—With the second molt the male assumes a form foreshadowing the true pupa, which may be called the pro-pupa.[a] The form is elongate oval; length 0.5^{mm}. The color is very pale yellow, with the antennæ, limbs, and wingpads, and two or three terminal segments of the abdomen, colorless. The legs and antennæ, as noted, have reappeared, and also prominent pads foreshadowing the wings of the adult. The eyes are dark purple and placed close together. The antennæ are very stout, and curved closely around the edge of the body as far as the anterior legs, where they bend inward. The

[a] The existence of a pro-pupa or a first pupal stage in the Coccidæ analogous to the first pupal stage of higher Hemiptera has also been affirmed by Dr. Fr. Loew. (Wiener Entom. Zeit., Jan., 1884, p. 13.)

wingpads are stout and almost entirely cover the abdomen. The terminal segment is still broad and flattened and bears two short spines, but the other characters have disappeared.

True pupa of male.—The true pupa resembles the previous stage, except that the members are longer and slenderer, and the prominent anal style has appeared. The pupa is pale yellow and purplish in color, darkest about the base of the abdomen, the head, antennæ, legs, wing sheaths, and style being almost colorless and transparent. The eye spots are dark purple. The antennæ extend nearly to the middle femora, and are not curved under the body as formerly, but are applied close to the sides with the apex free. The anterior legs are held forward, reaching slightly beyond the eyes. The middle femora rest transversely to the body, projecting somewhat beyond the margin of the abdomen, while their tibiæ form with them a right angle and reach nearly to the apex of the hind femora. The latter incline posteriorly, while the hind tibiæ are applied close to the sides of the body, except toward the tip, and reach nearly to the base of the style. The style is rather stout, conical, obtusely pointed at tip, and about as long as posterior tibiæ. Length, 0.8^{mm}, including style, which measures about 0.15^{mm}.

Mature male.—The general color is orange with a faint duskiness on the prothorax. The head is somewhat darker than the rest of the body. The eyes are dark purple, almost black. The antennæ are yellow, somewhat obscure or smoky. The legs and style are dusky, the latter paler than the former. The thoracic shield is regularly ovoid, compressed anteriorly, dusky in color, with margin brown, more distinctly so anteriorly; transverse band narrow, brown. Antennæ 10-jointed, two basal joints shortest, second nearly globular, inserted in the first; joints 4 and 5 subequal, longer than any of the others; joint 6 next in length, and joints 3, 7, and 9 shorter and subequal; joint 10 still shorter, conical. Antennæ somewhat hairy and nearly as long as the body of the insect. Wings faintly dusky, iridescent with yellow and green. Length of body about 0.6^{mm}; style, 0.25^{mm}.

Female, third stage.—After the second molt the females still appear pale yellow as before, with various larger and smaller transparent spots around the border of the body. The form is nearly circular, with greatest diameter averaging 0.56^{mm}. The sucking bristles are very prominent and long, three times the length of the insect. The last segment in this stage has practically the characters of the mature female, as follows: There are two pairs of lobes, the terminal ones largest and nearly three times as broad as the other lobes. Terminal lobes are rounded at the apex and are distinctly notched near the middle of the external edge. The second pair of lobes is smaller and narrower, and is also notched externally. Between the first and second lobe on either

side is a small spine, and two or three such spines are just back of the second lobe, while back of these are three stout teeth curving anteriorly. A still smaller blunt tooth sometimes occurs near the middle of the lateral margin. The segmentation of the body at this stage is quite distinct.

Mature female.—After reaching maturity the embryonic young are at first not visible, but later the body becomes filled with them. The mature female measures 0.8^{mm} wide by about 1^{mm} long.[a]

The following description of this stage is reproduced from Comstock:

> The body of the female is yellowish and almost circular in outline; the segmentation is distinct, tho not conspicuous. The last segment presents the following characters:
>
> There are only two pairs of lobes visible; the first pair converge at tip, are notched about midway their length on the lateral margin, and often bear a slight notch on the mesal margin, near the tip. The second pair are notched once on the lateral margin.
>
> The margin of the ventral surface of the segment is deeply incised twice on each side of the meson, once between the bases of the first and second lobes, and again laterad of the second lobe. On each side of each of these incisions is a club-shaped thickening of the body wall.
>
> There are two inconspicuous simple plates between the median lobes, and on each side similar plates extending caudad of the first incision, three small plates serrate on their lateral margin caudad of the second incision, and the club-shaped thickenings of the body wall bounding it, and three wide prolongations of the margin between the third and fourth spines. These prolongations are usually fringed on their distal margins. There are also, in some, irregular prolongations of the margin between the fourth spine and the penultimate segment.
>
> The first and second spines are situated laterad of the first and second lobes, respectively; the third spine laterad of second incision, and the fourth spine about one-half the distance from the first lobe to the penultimate segment.

SYSTEMATIC POSITION AND RELATIONSHIPS.

The San Jose scale was described by Professor Comstock from material collected in 1880 in Santa Clara County, Cal., on apple, pear, plum, and other fruit trees.[b] The relationships of this scale insect have been discust by various authors, notably by Prof. T. D. A. Cockerell, without, however, reaching a very good solution, in the judgment of the writer. Without going into a detailed technical discussion, the San Jose scale is quite as closely allied in structure, scale covering, and habit with the Aonidiella group as it is with the group including *ancylus* and *ostreæformis*. It is a very distinct and well-marked species, however, and is always easy of identification after one becomes once familiar with its principal characteristic structural features, and it is one of the few scale insects which can ordinarily be

[a] Rept. U. S. Dept. Agric., 1880, p. 304.

[b] Report of the Entomologist, in the Report of Commissioner of Agriculture for 1880 (1881), pp. 304, 305.

safely identified from the appearance of the scale covering and without being prepared for microscopical study.

Three varieties of the San Jose scale have been designated, none of which are valid. Of these *Aspidiotus perniciosus* var. *albopunctatus* Ckll. was described from twigs of a supposed orange seedling sent from Japan and stopt by Mr. Craw in his quarantine work in San Francisco. The twigs are thorny and may possibly be of the trifoliate orange or of some orange seedling, but whether of ordinary orange or tangerine or some other horticultural variety can not be determined. From the extreme unlikelihood of the San Jose scale attacking ordinary orange, the probability is very strong that these seedlings were either trifoliate or of the mandarin or tangerine types. At any rate, the scale itself is typical San Jose scale, and there is no basis whatever for tl e separation of these specimens as a variety. The character on which the variety was founded, namely, the white dot surrounded by a black ring marking the exuvia, is a feature which may be very commonly found in the San Jose scale from any source.

The other variety established by Mr. Cockerell is his *Aspidiotus perniciosus* var. *andromelas*, first described in California Fruit Grower, June 5, 1897, on a plant labeled "*Phœtenia glauca*," from Japan, also received from Mr. Craw. This variety is also based on the character of the covering scale, and is described as wholly black without any light dot and ring, a condition which is easily produced by rubbing or otherwise accidentally and may occur anywhere.

A third synonym of the San Jose scale is Maskell's species *Aspidiotus fusca*, described in the New Zealand Transactions, Volume XXVII, page 43, 1894, figures 6–9, Plate I. This insect was described from material collected in Australia on peach; and from Maskell's own figures and account of it, and also from the study made by Leonardi in Italy, and from the later note on the subject by Maskell himself in the Canadian Entomologist, it is evident that this species was based on material representing the last stage of the female of *perniciosus*, but before the secretionary supplement had been much if any developed, so that the second exuvium was still larger than the newly molted insect. This point can not, of course, be fully determined without an examination of type material, but there is very little doubt in the writer's mind of the correctness of this reference.

A fourth variety is *Aspidiotus perniciosus* var. *eucalypti* Fuller. A study of material received from Fuller of this variety indicates that it should not be referred to the San Jose scale at all, but is a good distinct species belonging to the genus Aonidiella, and the name becomes *Aonidiella eucalypti* Fuller.

No valid varieties or subspecies of the San Jose scale have therefore been found, and all of the points of infestation now known can be traced directly to the Chinese origin of the scale.

MEANS OF DISTRIBUTION.

From an economic standpoint the important considerations in the means of spread of this insect are those which affect its wide distribution from one part of the country to another. The transportation by nursery stock or scions or budding and grafting material, as indicated in the foregoing account of this insect, is unquestionably the usual and principal means of carrying the insect to a distance. The importance of this means of distributing various insects has only been fully realized in this country in the last few years, but the present instance and some other notable ones of like nature have emphasized the great danger incurred not only in the indiscriminate introduction of plants from foreign sources, but also in the carriage of plants from one part of the country to another without competent inspection.

The San Jose scale is also frequently carried about on fruit, particularly of the apple and pear. The young scale insect goes out on the fruit, and in the case of badly infested trees there is usually a good deal of scale on the fruit particularly, massed at the blossom and stem ends. The scale may go on breeding on such fruit and the young may be found crawling about on the fruit and in the boxes. Such fruit is commonly shipped to remote points, and infested fruit may be found quite commonly in the markets of this country; and when attention was drawn to the San Jose scale by its first developing in the East, infested fruit from California could be found in almost any of the fruit markets of the principal eastern cities.

The shipping of infested fruit from California had been going on for a great many years, and in spite of its wide dissemination in this country, and to some extent abroad, there is not, so far as the writer knows, a single authenticated instance of the scale having been established from such material. The possibility of it, however, undoubtedly exists, but the danger seems to be inconsiderable. The fruit is eaten in such places and the parings and waste material are usually disposed of in such a way that it would be very exceptional indeed for such fruit, or the young scale that might hatch on them, to get access to trees on which the scale could make lodgment. It would practically be necessary for the parings to be tied to a tree, or the fruit to be placed in the crotches of the tree, to secure infestation, and it is the belief of the writer that infestation from this source can be practically ignored. This has an important bearing on the legislation against American fruits enacted by various foreign countries, and certainly the history in this regard in the United States is well worth considering where such fruit was shipped about for years prior to the San Jose scale scare without restrictions. The wide distribution, therefore, of the San Jose scale is substantially limited to its carriage on nursery stock and cuttings.

The local spread of the insect from orchard to orchard and from tree to tree must also be brought about thru the agency of means other than those under the control of the insect itself. The female is wingless and after once becoming fixt can not move. The young lice, as before stated, are active, crawl rapidly, and may reach other trees, but this is rare unless the limbs interlace, since we have shown by breeding-cage experiments that the larvæ normally crawl but a few inches. Such spread, however, is comparatively insignificant except in the case of nursery stock, which is grown close together. It is possible that strong winds may carry the young bodily from one tree to another, or they may be floated on water to distant points, particularly in irrigated districts, but the principal method of the spread of these young lice is by means of other insects and by birds. The active young lice soon crawl upon any small winged insect, particularly if the latter be of a dark color, and may thus be carried considerable distances. They are frequently found crawling upon ants, which are great travelers. It is extremely probable that they also crawl upon the feet of birds, and may be transported by these carriers for many miles.

Some interesting observations have been made by Mr. Schwarz upon the transporting of these scale larvæ by other insects. A little black ladybird, *Microweisea* (*Pentilia*) *misella* Lec., which was very active in devouring scale larvæ, was unfortunately equally efficient in transporting many of these young lice to other parts of the tree or to other trees; in fact, it was difficult to find a single beetle which did not carry on its back at least one larva of the San Jose scale, and sometimes three or four were found upon a single wing cover of a beetle. The small black ant, *Monomorium minutum* Mayr, was particularly abundant upon pears, attracted by the juices emerging from cracks, and almost every one of these insects carried on its back one or more specimens of the young scale insects. Specimens of the little chrysomelid beetle *Typophorus canellus* Fab. were also found upon the trees. Both red and black specimens of this beetle occurred, and the interesting observation was made that while Aspidiotus larvæ crawled freely on the black individuals, no specimens were to be found upon the red ones. The same peculiarity was found to hold true with the ants. The red ant, *Formica schaufussi* Mayr, was abundant upon the pears, but no specimens were found bearing Aspidiotus larvæ, while, as just stated, the little black Monomorium was always found carrying them.

As illustrating this transportation of the scale by birds or insects the experience at Riverside, Md. (Bul. 3, p. 25), may be cited, and Professor Smith reports a similar instance in New Jersey, in letter of January 13, 1896.

In spite of the abundance of insects which may transport the larvæ the progress of the scale from infested trees to noninfested trees is

slow where trees are moderately widely separated, and usually an entire orchard will not become affected from a single original point for several years.

Occasionally the young scales may be locally transported by men or teams. An interesting case in point is given by Professor Rolfs. He states that some melons growing in an infested orchard were given by the owner to a friend, who took them away from the orchard in his wagon. A year later the scale developed on a tree under which the team had been hitched while the melons were unloaded. As this orchard was entirely free from the scale originally, it seems to be a reasonable inference that the young had crawled upon the wagon, harness, or melons, were conveyed a distance of 3 miles, and succeeded in gaining access to a tree which probably touched the wagon or team during the interval of unloading.

PARASITES AND OTHER NATURAL ENEMIES.

The following paragraphs, under the heading "True parasites," were prepared for this bulletin by Dr. L. O. Howard.

TRUE PARASITES.

Some eight species of true parasites have been reared from the San Jose scale in this country. Nearly all of these are widespread, occurring on the Pacific coast, and generally also in the East, and are found also in other parts of the world. None of them are specific enemies of the San Jose scale in the sense that they are limited to this species of scale, but all of them are general parasites on other armored scale insects. They are as follows:

Aphelinus fuscipennis Howard.
Aphelinus mytilaspidis Le Baron.
Aspidiotiphagus citrinus Howard.
Anaphes gracilis Howard.
Physcus varicornis Howard.
Prospalta aurantii Howard.
Ablerus clisiocampæ Ashmead.
Rhopoideus citrinus Howard.

Of these *Aspidiotiphagus citrinus*, *Prospalta aurantii*, *Aphelinus fuscipennis*, and *Aphelinus mytilaspidis* are of very wide distribution. *Aspidiotiphagus citrinus*, for example, originally described from California in 1891, is now found in many other portions of the United States, in the West Indies, Italy, Austria, Ceylon, China, Formosa, Japan, Cape Colony, Queensland, South Australia, and Hawaii, and this remarkable distribution is practically followed by the other three.

The most important of these parasites is the little *Aphelinus fuscipennis*. It was reared in large numbers by Mr. Coquillett, in California, many years ago, where it was found to breed thruout the year,

specimens being reared as late as November 10. It was subsequently reared many times by Mr. Alexander Craw, Mr. E. M. Ehrhorn, and others, in California. In the East it attacked the San Jose scale at the very outset, having previously existed in this part of the country as a parasite of other species of Diaspinæ. It was reared in this office from material collected at Riverside, Md., and Charlottesville, Va., and also from the material collected in the first orchards found infested, by Prof. J. B. Smith, of New Jersey. Professor Forbes has reared it in Illinois from the San Jose scale, and it has often been reared in Washington. That this insect has been steadily on the increase seems likely, but it is also probable that there is a certain periodicity in its increase. In Bulletin No. 57 of the Maryland Agricultural Experiment Station, published in August, 1898, Prof. W. G. Johnson stated that he did not think it possible to secure any immediate beneficial results from this parasite in the State of Maryland. He said that in all his efforts to secure them in his breeding cages he had been obliged to inclose hundreds of thousands of scales to obtain one parasite. Less than two years later, however,[a] he stated that in a new locality for the San Jose scale, near Easton, Talbot County, Md., he found the parasites in enormous numbers. A quantity of small branches incrusted with the scale were brought to his laboratory and inclosed in breeding tubes. Much to his surprise these tubes were swarming with parasites a few days later. From one tube 1,114 specimens of *Aphelinus fuscipennis* were taken, while a second tube gave 432, a third 1,478, and a fourth more than 1,000. The other scale insects infested by this parasite are *Aspidiotus rapax* Comst., *Aspidiotus euonymi* Targ., *Lepidosaphes gloverii* Pack., and *Lepidosaphes ulmi* L.

Aphelinus mytilaspidis Le Baron is another important parasite which was reported in earlier publications as attacking the San Jose scale in California, where it was reared in Santa Clara County by Mr. E. M. Ehrhorn. It is also a common and widespread species, and infests, aside from the San Jose scale, *Lepidosaphes ulmi*, *Chionaspis pinifoliæ* Fitch, and *Diaspis carueli* Targ. In the East it is the commonest parasite of the oyster-shell scale of the apple. It has only recently been found to attack the San Jose scale, and it is an encouraging feature that this and other eastern species have at last found a host satisfactory to themselves in *Aspidiotus perniciosus*. It was last year (1905) reared at this office from San Jose scale collected at Washington, D. C., by Mr. A. A. Girault, and at Youngstown, N. Y., by Mr. A. L. Quaintance.

Aspidiotiphagus citrinus Howard (fig. 7) is one of the most important parasites of armored scales in California, to which State it was evidently imported from oriental regions. In California it has been

[a] Bull. No. 26, new series, Division of Entomology, U. S. Dept. of Agr., pp. 73, 74.

repeatedly reared from the San Jose scale, but it is also known to attack *Chrysomphalus ficus* Ashm. and *C. aurantii* Mask. variety *citrinus* Coq. It has made its way to the East and has been reared from the San Jose scale received from Hampton, Fla., where it was collected by Mr. A. L. Quaintance. This species seems to be found only in the warmer countries, and has not been found north of Florida in the East as yet.

Anaphes gracilis Howard, which was reported in Bulletin No. 3 as originally reared from specimens collected at Riverside, Md., and later from twigs received from Charlottesville, Va., has not again been reared in this office from the San Jose scale, and the doubt exprest in our original note may be valid, namely, that this species may have been a parasite of some other scale insect, probably the oyster-shell scale, present on the twigs at the same time. The type of the species was reared from the oyster-shell scale of the apple, and it is quite likely to be an egg parasite only.

FIG. 7.—*Aspidiotiphagus citrinus*, greatly enlarged (from Howard).

The four species just mentioned were recorded in Bulletin No. 3. During the summer of 1905 three other species have been reared by Messrs. Quaintance and Girault. These are as follows:

Physcus varicornis Howard was reared from material collected by Mr. Quaintance, May 30, 1905, at Hampton, Fla. There remains a little doubt as to the parasitism of this species on *perniciosus*, as according to the note there may possibly have been other hosts present. The known hosts of this species are *Aspidiotus ancylus* Putn., *Chionaspis quercus* Comst., and *Chionaspis americana* Johnson.

Prospalta aurantii Howard (fig. 8) was reared from the San Jose scale July 31, 1905, from material collected from an infested pear tree on the grounds of the Department of Agriculture, at Washington. This parasite affects no less than nine distinct species of scale insects, and has been reared from material collected in California, Florida, District of Columbia, New York, New Mexico, and Illinois.

Ablerus clisiocampæ Ashm. (fig. 9) was reared in the summer of 1905 by Messrs. Quaintance and Girault from the San Jose scale occurring upon pear upon the Department grounds, at Washington.

FIG. 8.—*Prospalta aurantii*, greatly enlarged (from Howard).

It was also reared from *Diaspis pentagona* Targ., occurring upon the grounds of the Department. It affects also *Chionaspis furfurus* Fitch, and is known to occur in North Carolina, in Illinois, and in the District of Columbia.

FIG. 9.—*Ablerus clisiocampæ*, female, greatly enlarged (from Howard).

Rhopoideus citrinus How. was reared in 1885 by Mr. Albert Koebele at Truckee, Nevada County, Cal., from *Aspidiotus perniciosus* on pear, and was described by the writer in the proceedings of the U. S. National Museum, No. 1142, October 4, 1898. This record was

overlooked in earlier publications from this Bureau, and the species has not since been reared from any scale in any part of the country. The Koebele 1885 specimens are unique so far as known.

PREDACEOUS INSECT ENEMIES.

NATIVE AND INTRODUCED ENEMIES OF OTHER SCALE-INSECTS.

Practically all of the scale-feeding Coccinellidæ, or ladybirds, may feed on the larvæ or older specimens of the San Jose scale. A dozen or more different species of ladybirds have been recorded in this country as attacking this scale insect. Our most important native scale-feeding ladybird (*Chilocorus bivulnerus* Muls.), commonly known as the twice-stabbed ladybird, and represented by one species or by a number of closely allied forms in different sections of the country, has not proven very efficient against the San Jose scale, at least in the East, altho commonly found in infested orchards. Its presence in eastern orchards, however, may often be accounted for by its being attracted by other native scale insects present in the same orchards. It is a slow breeder, having in the North at least but one brood annually, and seems to give very little promise of being of any great value as a means of controlling the San Jose scale in these sections of the United States. In California and elsewhere on the Pacific coast, but particularly in the Pacific coast region, the twice-stabbed ladybird is a much more active and important means in keeping the San Jose scale in check. It has been reported as multiplying enormously in infested orchards in California and almost effecting the extermination of this scale. Such a report was sent to us by Mr. N. W. Motheral relative to orchards in Tulare County, Cal.[a]

A large number of Coccinellidæ imported by Mr. Koebele into California and colonized there have been reported as attacking the San Jose scale. The following species have been observed to have developed this habit: *Rhizobius debilis* Black, *Orcus australasiæ* Boisd., *Rhizobius lophanthæ* Blaisdell, *Orcus chalybeus* Boisd., and *Microweisea*[b] (*Pentilia*) *misella* Lec. The last named of these only is of any importance as a means of controlling the San Jose scale.[c] Another

[a] See Insect Life, Vol. V, p. 53.

[b] See Cockerell, Can. Entom., Vol. XXXV, No. 2, p. 38, February, 1903.

[c] The efficiency against scale insect pests of citrus trees of certain of Mr. Koebele's importations of foreign ladybirds into California led the State Horticultural Society of New Jersey to secure in 1896 from the State legislature an appropriation of $1,000 for the purpose of importing into the State of New Jersey the natural enemies and parasites from other States and countries. Acting under this appropriation, Dr. John B. Smith, entomologist of the experiment station of New Jersey, visited California and sent a large quantity of several species of Australian ladybirds to various places in New Jersey, and some to Washington, D. C. Subsequent records of these importations indicated that they were all unsuccessful, and not a sign of the imported insects could be found in 1897. (See Report of Entomologist, New Jersey, 1897.)

and very interesting species of Microweisea, recently described, also attacks the San Jose scale, and is referred to below.

Rhizobius lophanthæ was originally described from specimens found preying upon the San Jose scale at San Diego, Cal., but belongs to a lot which was introduced by Mr. Koebele on his first Australian trip (1888–89) and subsequently lost sight of, and was described by Doctor Blaisdell under the supposition that it was a new California species.

Of our native predaceous insects attacking the San Jose scale, the most useful and interesting is the little coccinellid *Microweisea misella* (fig. 10), which in both the larva and beetle state feeds upon this scale. It has a very wide range, occurring thruout the East and also

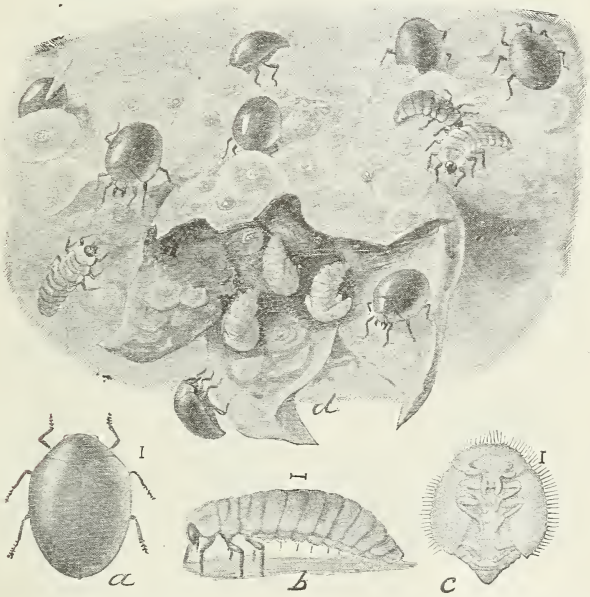


FIG. 10.—*Microweisea* (*Pentilia*) *misella*: *a*, beetle; *b*, larva; *c*, pupa; *d*, blossom end of pear, showing scales with larvæ of Microweisea feeding on them, and pupæ of Microweisea attached within the calyx. All greatly enlarged (from Howard and Marlatt).

in California, and began to attack the scale in numbers in the East in the first infested orchards discovered. This beetle was figured and its habits briefly indicated in Bulletin 3. The parent beetles prefer the full-grown female scales, and may frequently be observed standing astride the scale, almost on end, pushing their heads under the margin of the protecting scale to get at the soft, yellow insect beneath. The larvæ of these beetles seem to feed more abundantly on the young scales. Their mode of attacking the older scales was not observed. The egg of this particularly useful coccinellid has not been found, but a favorite place for pupation was discovered within the calyx of the pears. This cavity is often literally filled with a mixture

of young and old scale-insects, and frequently contains full-grown Pentilia larvæ, their pupæ, and freshly issued beetles. (See fig. 10.)

This beetle was originally believed to be essentially an eastern species, and the fact that it attacked the San Jose scale so efficiently at the very outset was an interesting entomological experience, and led Doctor Howard to suggest its immediate introduction into California, and one colony was sent, in 1894, to Professor Woodworth, at Berkeley. Our account of this useful beetle having come to the attention of Mr. J. E. McIntyre, of Lespe, Cal., he urged us to procure for him some living specimens. Having already sent material to Mr. Woodworth, we were not immediately able to get a supply of the insects for a sending, but at this juncture we received from Mr. G. W. Harney, of Marysville, Cal., some beetles for determination, which proved to be *Microweisea misella*. He reported that in the mountainous regions of Yuba County many apple trees had been very badly infested with *A. perniciosus*, and that hundreds of these little ladybirds were found preying on the scale. The occurrence of this ladybird in California as thus determined, and the fact that it there had the same useful habit, was a most interesting discovery. We immediately had Mr. McIntyre's request transferred to Mr. Harney for attention. It is more than likely that this little beetle is already widely distributed over the Pacific slope, and it may prove to have a continental distribution instead of being restricted to the East, as originally supposed.

Another species of about the same size as *Microweisea misella*, but dark wine-red in color and representing a distinct species, has been under observation for some time by Mr. Frederick Maskew in southern California, and at the time of the writer's visit to California in the autumn of 1903 his attention was called to this scymnid, and some material was collected and submitted to Mr. E. A. Schwarz, who pronounced it to be an undescribed species. Mr. Maskew states that this little scymnid is always associated with the San Jose scale, and seems to be doing pretty good work against it. Mr. Schwarz has published a description of it under the name *Pseudoweisea suturalis*.[a]

A small predaceous beetle, *Collops quadrimaculatus* Fab., was observed by Mr. Schwarz at Charlottesville, Va., feeding on the larvæ of the San Jose scale. This beetle belongs to the family Malachiidæ, concerning the life history and food habits of which very little is known. Evidently these beetles are in part at least predaceous, as evidenced by this observation by Mr. Schwarz. This beetle is, however, not abundant enough apparently to have any practical value as a means of controlling the San Jose scale.

[a] Proc. Ent. Soc. Wash., Vol. VI, No. 2, April, 1904, pp. 118, 119 (issued May 21, 1904). The name Pseudoweisea was used by mistake for Microweisea.—Ed.

THE ASIATIC-LADYBIRD ENEMY OF THE SAN JOSE SCALE.

Thruout the region investigated in China and Japan (see pp. 11–15), wherever the San Jose scale occurred, apparently the chief natural agency in keeping it in check was a small ladybird, *Chilocorus similis* Rossi (figs. 11, 12, and Pl. VII), which feeds upon the scale voraciously. This beetle is almost identical in appearance with the twice-stabbed ladybird of this country, *Chilocorus bivulnerus*, in the adult stage, but in the larval stage differs from it distinctly in coloration.

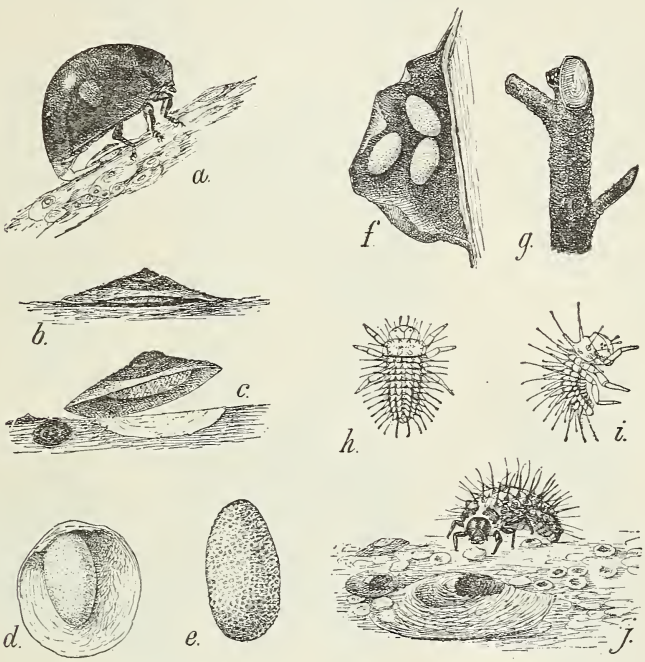


FIG. 11.—Asiatic ladybird (*Chilocorus similis*), oviposition and early larval stages: *a*, beetle in act of thrusting egg beneath scale; *b*, scale slightly raised, showing edge of egg beneath; *c*, scale lifted from bark, showing manner of attachment of egg to the inner surface; *d*, view of egg in the scale; *e*, egg magnified to show sculpturing; *f*, three eggs placed under flap of bark; *g*, same, natural size; *h*, *i*, dorsal and lateral views of newly hatched larva; *j*, larva, first stage, feeding on mature and young scales. All enlarged except *g* (author's illustration).

The Asiatic species has a skin of a reddish or flesh tint, with black spines, while the general color of the larva of the native species is a dull gray, which, with black spines common to both, gives the latter a very much darker appearance. There are also certain minute structural characters which can be made out only with the use of the microscope. There is, furthermore, a very distinct difference in the habits of the two species, the Asiatic ladybird going through an indefinite number of generations—four or five annually, depending upon the climate and latitude—and the American species having much fewer

and often but a single generation annually. The slowness of breeding of the American species is a very great bar to its usefulness in the latitude which includes the principal deciduous-fruit interests of the United States.

These facts were thoroly demonstrated from the breeding records of the material sent from China and Japan. Several sendings were made by the writer, but unfortunately most of the specimens died in transit or during the first winter. Two individuals, however, survived, and during the first summer, that of 1902, from these two some 5,000 or more beetles were secured. The breeding was first carried

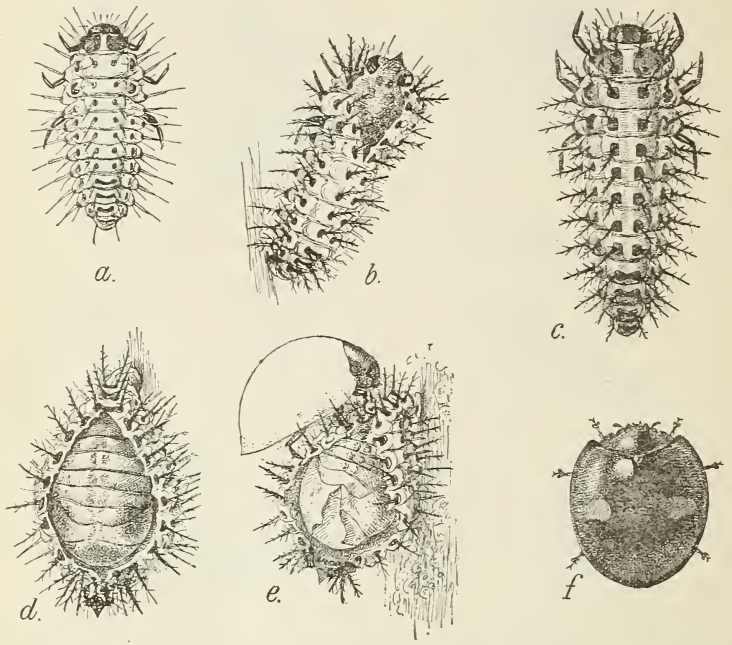
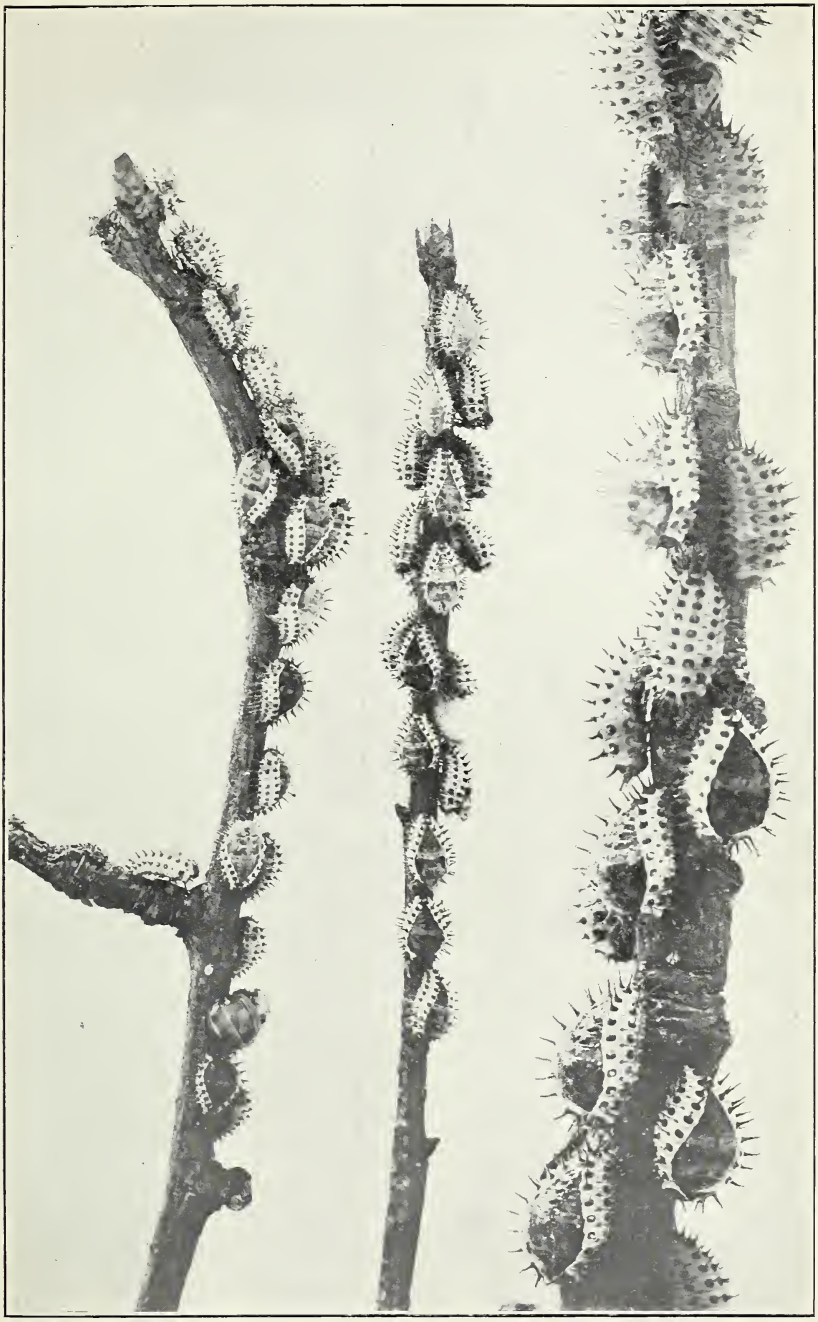


FIG. 12.—Asiatic ladybird (*Chilocorus similis*), later larval stages, pupa, and adult insect: *a*, second larval stage; *b*, cast skin of same; *c*, full-grown larva; *d*, method of pupation, the pupa being retained in split larval skin; *e*, newly emerged adult not yet colored; *f*, fully colored and perfect adult. All enlarged to the same scale (author's illustration).

on in cages (Pl. VIII), but afterwards the beetles were liberated in the small experimental orchard attached to the insectary of the Bureau.

A good many colonies were sent out to different States, both north and south, in the summer of 1902, many more in the summer of 1903, and a few additional colonies in 1904. Many of these colonies were liberated under rather unfavorable conditions, or, in other words, where there were very few infested trees, and the beetles probably became scattered and lost. The best success came with certain colonies sent to Georgia, and especially the notable case of the colony at Marshallville. This last was in an orchard containing some 17,000



PUPATING LARVÆ OF CHILOCORUS SIMILIS ON THE TERMINALS OF TWIGS IN DEPARTMENT ORCHARD. (AUTHOR'S ILLUSTRATION.)

CAGES USED IN BREEDING ASIATIC LADYBIRD (CHILOCORUS SIMILIS).
(AUTHOR'S ILLUSTRATION.)

peach trees, covering about 75 acres, and adjoined a very much larger orchard belonging to the same owner, containing 250,000 trees. The ladybirds were liberated in August, 1902, in the smaller orchard. An examination of this orchard in July, 1903, indicated that the beetles were rapidly spreading, and that they would soon cover the smaller orchard. An estimate at this time of the number of ladybirds in all stages placed the total at somewhere between 25,000 and 40,000, and from observations breeding evidently continued at this point up to January. There was therefore in this latitude at least a very flattering outlook for good results from the imported beetle.

None of the colonies sent to northern States, that is, north of the District of Columbia, became established nor gave any useful results, and subsequent experience, and particularly the elaborate tests conducted by Dr. J. B. Smith, in New Jersey, would indicate that there is very little likelihood of usefulness from this beetle for northern fruit regions. That it may be established in the South was fully demonstrated by the experience noted in Georgia and by the experience in the orchard attached to the insectary of this Bureau, and in some other similar experiments where the results were perhaps less marked.

At the time that this beetle began to demonstrate its probable considerable usefulness in Georgia and elsewhere in the South, the practical value of the lime, sulfur, and salt wash became fully established, and all commercial orchards were regularly subjected to spraying operations with this mixture. The result was that the scale food of the imported beetle was almost completely destroyed, and this was true in the principal orchards where it was doing its best work. As a consequence all of the beetles starved or their numbers were greatly reduced.

The local stock of ladybirds in Washington practically disappeared with the gradual extermination of the scale food, and by the action of a native parasite which began to attack it after the first year. This parasite is one that we had previously reared from native ladybirds and had supposed it to be a secondary parasite; but the fact that it is a primary parasite became fully demonstrated, and it attacked the Washington colony with such vigor as to practically exterminate it. Fortunately this same parasite does not seem to have been equally active in the case of the southern colonies, but it will undoubtedly always be a bar to great usefulness from this and allied ladybirds.[a]

A very serious difficulty in the introduction and establishment of a predaceous insect like this Asiatic ladybird beetle, which has rather limited powers of flight and is not carried about on nursery stock as are true parasites, is the very scattering nature of infestation in this country. In spite of the fact that the San Jose scale has become so

[a] See Proc. Ent. Soc. Washington, Vol. V, No. 2, pp. 138, 139, 1903.

widely distributed and is doing so much damage to orchards, it is still far from being universally present, and occurs after all in a very scattering way in orchards here and there, with often 20 or 30 miles between places of infestation. In Japan and China, where the Chilocorus occurs rather generally, it finds food for itself in every country and city dooryard, either the San Jose scale, or, in Japan particularly, the white peach scale (*Diaspis pentagona*), on which it also feeds. The stock of ladybirds, therefore, is always kept up in greater or less numbers, ready to take hold of any unusual scale increase. In this country, if the local food supply is stopt by spraying operations or exhaustion, the ladybird necessarily dies, and very rarely will go far enough to find another infested orchard and a new food supply. Ultimately, when the San Jose scale occurs everywhere, predaceous ladybirds like the Asiatic species will undoubtedly become much more useful than they are under present conditions.

Neither the Asiatic ladybird nor any other predaceous insect—and this is true also of the chalcidid parasites, tho perhaps in a less degree—can ever be expected to so thoroly exterminate the San Jose scale as to give sufficient protection for commercial orchard purposes, where absolutely clean or unspotted fruit is an essential. Predaceous and parasitic insects can only survive in connection with their host species, and therefore ultimately there must be a natural balance which will fluctuate from year to year or period to period, in which alternately the parasite and the host insect get the upper hand, but both necessarily being continuously present. Where substantially clean fruit must be had, as for shipping and export purposes, spraying or some other direct means of control must be practised; and now that an inexpensive tree wash for the San Jose scale has been discovered, it is very much to the advantage of everyone to spray regularly, rather than trust to control by natural enemies.

The importation of the Asiatic ladybird and the action of other predaceous enemies and of parasites can not, however, work anything but good. These feed upon or parasitize and destroy scale insects and will ultimately greatly reduce the virulence of the attacks of the San Jose species. The larva of the Asiatic ladybird was observed to eat the young of the San Jose scale at the rate of five or six insects to the minute, and even on an average of but one a minute a total of 1,440 scale insects per day would be destroyed. The appetite of these larvæ seems to be never satisfied, and they are eating practically all of the time. The adults also feed actively on the scale. In addition to their greater or less efficiency in generally checking the rapid multiplication of the San Jose scale, they and other natural enemies will ultimately be of special service in the control of the scale in private grounds and in small orchards and gardens the owners of which would not, under ordinary circumstances, practise regular spraying operations.

It is evident, from the records of true parasites given at the outset, that native parasites are beginning more and more to attack the San Jose scale. The native predaceous beetles will follow suit, and undoubtedly as years go on the seriousness of San Jose scale infestation will diminish, as, in fact, it has already done in California and perhaps noticeably also already in some sections in the East.

FUNGOUS AND OTHER DISEASES OF THE SAN JOSE SCALE.

Scale insects are more or less subject to control by fungous and other diseases, and the San Jose species is no exception to this rule. Control by these agencies is particularly efficient in the moist Tropics, so much so that most scale insects are practically wanting in such regions. The armored scales, such as the San Jose scale, are rarely to be met with in tropical regions in any numbers, and where found are diseased in a large percentage of cases. The mealy bugs, however, are comparatively immune. The efficiency of these diseases as a means of control lessens as one leaves the Tropics, but in the subtropical regions of the United States, and even in the temperate regions, the San Jose scale has in many instances been very generally exterminated by disease. Several of these diseases are obscure and have never been scientifically studied, nor have they developed any fruiting stage so that they could be studied with any degree of accuracy.

In the early work with the San Jose scale in California, Mr. Coquillett reports the death of the San Jose scale from an unaccountable cause, supposedly disease, in Pasadena County, Cal., on pear trees which had not been treated with any kind of insecticide. Specimens of twigs covered with dead scales were submitted to the Bureau of Plant Industry for examination. No specific disease germ could be discovered, but this does not preclude the explanation of some definite disease as the cause of the death of the scales. Similar cases have come up in the East several times, the first perhaps occurring at Riverside, Md., in the early history of the scale, where, without treatment, the scale died in a very large percentage thruout a considerable orchard. A number of similar cases were reported by Doctor Howard in Bulletin 12, one from Tifton, Ga., where a careful count of the scales showed that on one twig out of 183 scales 4 were living; on a second, out of 723 scales 2 were living, and on a third, out of 579 scales 28 were living, giving 34 living scales out of 1,485, a mortality rate of 97.7 per cent. A similar case was reported also from Wadley, Ga., by Professor Starnes, and Professor Alwood has noted the same conditions at Vienna, Va. Doctor Howard also records the fungus-infested scale reported by Doctor Fletcher at Fruitland, Ontario, altho here the fungus or disease is probably a different one.

A more promising and important disease of the San Jose scale is the cosmopolitan scale-insect parasitic fungus *Sphærostilba coccophila*,

which Professor Rolfs, of the Florida experiment station, identified and discust at length in Bulletin 41 of that station, published in 1897. This disease is common to other species of scale insects, is widely distributed in Florida and elsewhere in the Southern States, and was found to attack the San Jose scale in Florida very efficiently.

As outlined by Professor Rolfs, a San Jose scale attacked by this fungus is usually transformed into a mass of mycelia before there is any external appearance of change. When the body of the insect has been consumed a bright, orange-colored protuberance forms at the base of the scale, or at times it breaks thru the protecting cover of the insect. This orange-colored protuberance is the most conspicuous part of the fungus and the only portion visible to the unaided eye. It varies in size from an eighth to a fortieth of an inch. Those that average about one-sixteenth of an inch are most abundant under favorable conditions. These protuberances are the spore-bearing bodies, and contain spores in great numbers. These orange-colored spore-bearing bodies are developed and mature within six weeks from the time of infection, and countless numbers of spores are liberated from them during rains and are washed down the trees and sometimes to the ground. Other and smaller spore bodies are eventually produced from the germination of these, and are carried about by the air or other means, and thus extend the infection. The biology of this fungus is rather technical and complicated, and need not be gone into in detail.[a]

Professor Rolfs demonstrated experimentally that this fungus could be transferred from tree to tree artificially. His process was to inoculate acid bread with pure cultures of the fungus, and three weeks later to break up a piece of bread about an inch square in cold water, and apply to a scaly tree by means of a sponge or cloth or by spraying. The applications were made in midsummer, and the observations as to results late in February. Out of eight experiments four were successful, three unsuccessful, and one doubtful, the tree having in the meantime died. A good deal of interest was aroused by this publication of Professor Rolfs's, and experiments with this fungus were made in Georgia and by entomologists to whom cultures were distributed in the North and West. The results from these experiments in the more northern regions were not, as a rule, very satisfactory, and the fungus has not demonstrated great practical merit outside of Florida and perhaps southern Georgia. Undoubtedly, however, it is a very valuable aid in the control of the San Jose scale thruout the Gulf region, where high temperatures associated with sufficient humidity occur.

The most careful experimental work with this fungus was that conducted by Prof. J. B. Smith in New Jersey. While nearly all the

[a] See Bul. No. 41, Florida Agric. Exp. Sta., 1897.

experiments made by Doctor Smith were barren of results, one yielded rather notable success. This was in the orchard of Mr. Horace Roberts, at Fellowship, N. J. Twigs from Florida bearing San Jose scales infested by the fungus were tied to branches of infested trees about the middle of June. Toward the end of September Doctor Smith found the fungus upon almost all of the trees upon which twigs had been tied. He reports that it had spread pretty well over the trees, and in some cases its presence was obvious from the surface of the ground to the extremity of the branches, hundreds of patches of the orange fruiting processes being everywhere noticeable. In no case, however, so far as Doctor Smith observed, had the disease spread to any adjacent trees, unless in a less visible stage, and by no means all of the scales on the trees containing these twigs were dead.

Various saprophytic fungi which develop in diseased or dying wood are sometimes so closely associated with the scale, or in fact grow on the scale as well as on the wood, that the inference is a very natural one that the scale is being killed by these fungi. Examples of two such fungi have recently been sent to us for examination and were submitted to the Laboratory of Plant Pathology of this Department for investigation. The following report indicates their nature:

We find two species of fungi present upon these specimens. The most conspicuous form is *Micropera cotoneastri* (Fr.) Sacc. The fungus forms small, black, somewhat pulvinate masses on the surface of the bark, sometimes covering old scales. The plant is not mature and shows in only a few instances pycnospores. It is not an uncommon fungus upon diseased or dying branches of fruit trees and other closely related rosaceous plants. Its relation to the scales present is probably always accidental. The fungus probably develops more readily upon the twigs which have been injured or partially killed by the scale.

There is also another fungus present in a considerable quantity on some of the twigs. It consists of minute black, slender stipitate bodies a few millimeters high. This is also immature, showing only conidia. It is probably *Spinctrina cerasi* B. & C. In the absence of the ascigerous form of the fungus it is impossible to state positively that this is the species. As in the case of the other fungus mentioned, it probably bears no parasitic relation to the scales present, as it usually occurs on dead or dying branches of fruit trees.

The first fungus mentioned (Micropera) is the one most closely associated with the scales.

The plan of using contagious insect diseases to destroy important pests, such as the San Jose scale, is a very attractive one, and in the case of the San Jose scale well worthy of more careful study than has so far been given it. It is possible that some of the obscure forms of disease which have already appeared in northern districts, as in Maryland, Virginia, and in the State of Washington, may be capable of artificial propagation and distribution, and yield results of distinct value in the control of the scale. All of these fungous and other diseases will undoubtedly become more efficient with the more wide and general distribution of the scale.

MEANS OF CONTROLLING THE SAN JOSE SCALE.

INSECTICIDE APPLICATIONS.

Active experimentation with different remedies for the San Jose scale was instituted by this Office promptly after the discovery of the occurrence of this pest in eastern orchards and nurseries. A full record of these early experiments is given in Bulletin No. 3 (new series) of this Bureau, pages 56 to 71. The subject of these experiments will not be gone into in detail. They covered the use of the lime-sulfur washes employed against the San Jose scale in California, the hydrocyanic-acid-gas treatment for orchards and nursery stock, lye washes, pure kerosene, kerosene-soap emulsions, resin washes, and soap washes. The early experience with the lime, sulfur, and salt wash was unfavorable, largely due apparently to the fact that the observations on the trees treated were not continued long enough to note the effect of the late summer results. Good results were obtained with the kerosene emulsions, and particularly with the soap washes, and the fish-oil-soap wash became one of the standard means of controlling the scale and is still among the best and safest washes to be used, altho rather more expensive than necessary, except where only a few trees are to be treated.

The subject of remedies was promptly taken up by different experiment station entomologists in the East, and a vast body of experimental data is now on record in various station publications. The study of the subject of remedies has also been continued by this Bureau and reported in different bulletins. The lime, sulfur, and salt wash at first reported on adversely by us was afterwards demonstrated to be of real value, and experimental work was taken up, first by the Illinois Experiment Station, under Professor Forbes, and subsequently by other stations, and it has now come to be the generally accepted remedy for the San Jose scale. Without going at all in detail into the subject historically, it is sufficient for the purpose of this bulletin to reproduce the recommendations for the control of the San Jose scale substantially as given in the fourth revised edition of our Circular 42.

In addition to the standard remedies mentioned below a great many proprietary substances have appeared, and some of these have some merit. The best of these are certain merchantable brands of lime-sulfur compounds, and oils which have been treated by some secret process to render them miscible in water. The predominating constituent of the latter is mineral oil, and the resulting mixture, which is not apparently an emulsion, is undoubtedly of value if used in sufficient strength to get the required amount of oil on the trees. There is no advantage in using any of these compounds over the standard insecticides, and their greater cost is a distinct objection, together

with the uncertainty of composition. Nevertheless, where only a few trees are to be sprayed and the owners would probably not go to the trouble of preparing a standard emulsion or the lime-sulfur wash, the use of miscible oils or ready-made lime-sulfur washes is a good deal better than nothing, and may give very good results. Space does not permit the mention and discussion of a number of other mixtures which have not proven satisfactory nor the equal of standard means of control. Some of these have been experimented with somewhat extensively by different experiment station entomologists.

The methods of control which have been especially followed in the Eastern States are (1) the lime-sulfur wash, (2) the soap treatment, (3) treatment with pure kerosene, (4) treatment with crude petroleum, (5) treatment with mechanical mixtures of either of the last two oils with water, and (6) petroleum emulsion with soap. All of these methods have proved themselves to be successful against the San Jose scale when properly carried out. As compared with the lime-sulfur wash, the others mentioned are more expensive, and the two oils, unless very carefully applied, are likely to injure the treated plants and are now seldom used. One's choice of method must therefore be governed by availability, special needs, and experience. In the main these remedies, including the lime-sulfur wash, are winter treatments and may be employed at any time when the trees are in dormant, leafless condition. The weaker oil-water mixtures and the emulsions may, however, be used in the growing season. The treatments enumerated are all for trees in the orchard. Nursery stock badly enough infested to require such treatment is best destroyed. For the general disinfection of nursery stock the hydrocyanic-acid-gas treatment is the standard and only satisfactory means.

THE LIME-SULFUR WASH.

In California, where this scale insect first occurred, the standard remedy for it is the lime, sulfur, and salt wash, a mixture formerly used as a sheep dip in Australia and employed with little change against the San Jose scale, and by a lucky chance proving effective. This wash was naturally first thought of on the discovery of the San Jose scale in eastern orchards. The earlier tests, however, conducted by this office in 1894, were unfavorable, and the experimentation which followed resulted in the demonstration by ourselves and others of several distinct and valuable methods of control noted below. Later studies of the action of this wash in California led the writer in 1900 to give it a further careful trial in the East, with most successful results, demonstrating that with favoring conditions, i. e., absence of dashing rains for a few days subsequent to the application, it would give just as good results in the Eastern States as on the Pacific coast.

A year later (1901–2) very elaborate tests conducted by Doctor Forbes in Illinois showed that fairly hard rains will not always invalidate spraying with this mixture. A vast amount of experience of the most practical kind since gained, contributed to by all the eastern experiment stations and by the big commercial fruit growers of the Middle and Eastern States, has fully demonstrated the practical merit of this wash and its superiority to others in point of safety to trees and in cheapness. The wash is furthermore a valuable fungicide and is notably useful against the peach leaf curl, sprayed trees being practically immune from this disease, so that the cost of treatment is often more than made good by the fungicidal benefit alone. Its disadvantages are the difficulty of preparation and the heavy wear which it entails on apparatus—objections, however, which do not offset its notable advantages, particularly for commercial orchard work or where the number of trees to be treated is sufficient to warrant the trouble of its preparation. It is, in fact, the standard spray now used in commercial orchards for the San Jose scale.

In the matter of composition of the wash scarcely any two experimenters agree. Salt was a part of the original composition of the sheep dip and has long been retained, with the idea that it added, perhaps, to the caustic qualities, and particularly to the adhesive nature of the wash. For the latter purpose a very small amount only, 1 or 2 pounds to the bushel of lime, need be added, following the custom in the preparation of whitewash mixtures. In practical experience, however, the salt seems to have been of very little benefit and is therefore omitted in the formula now given. The proportion of lime and sulfur is a matter of some indifference. The mixture obtained is sulphide of lime, and if an excess of lime is used it simply remains undissolved in the mixture and adds to the whitewashing character of the application. Too much lime is distinctly objectionable, however, because of the greater difficulty of spraying and harder wear on the pump and nozzles. The formula here given is substantially the one which has been hitherto recommended by this Bureau, reduced to the 45 or 50 gallon basis, or the capacity of the ordinary kerosene barrel commonly used in its preparation by the steam method.

Unslaked lime	pounds	20
Flowers (or flour) of sulfur	do	15
Water to make	gallons	45 to 50

The flour of sulfur, although requiring somewhat longer cooking, seems to make as good a wash as the flowers of sulfur, but an hour of thoro cooking is ample for either. Good quality stone lime should be secured and slaked in a small quantity of hot water in the cooking vessel, say one-third the full dilution. The sulfur, previously mixt up into a stiff paste, should be added at once to the slaking lime. The

STEAM PLANTS FOR COOKING LIME-SULFUR WASH.

(From Quaintance.)

whole mixture should be boiled for at least one hour, either in an iron kettle over a fire out of doors or in barrels by steam (see Pl. IX). Prolonged boiling increases the percentage of the higher sulphides, but the practical end is obtained with a boiling of the time indicated. In the process of making, the color changes from yellow to the clear brown of sulphide of lime, except for the excess of lime floating in it. After an hour's boiling the full quantity of cold water can be added, and the mixture should then be promptly applied in order to get its full strength before the higher sulphides are lost by cooling and crystallizing out. In transferring to the spray tank it should be past thru an iron screen or strainer, and the tank itself should be provided with an effective agitator.

The wash is a winter application and can not be applied to trees in leaf. It may be applied at any time after the falling of foliage in early winter and prior to the swelling of the buds in spring. It will probably be necessary also to make this application every year, or at least as often as the San Jose scale develops in any numbers. The wash kills the San Jose scale not only by direct caustic action, but apparently also by reason of the coating on the trees, which remains in evidence until midsummer or later, and may kill or prevent the settling of any young scale insects which may come from parents escaping the winter action.

Two applications may be given badly infested orchards—one in late fall, the other in late spring. Where but one application is given, the late spring just before the buds open is the best time.

The wear on pumps and nozzles can be kept to a minimum by carefully washing the apparatus promptly after use. The Vermorel nozzle is the best one for the wash, and additional caps may be secured to replace worn ones. The use of an air or other gas pressure pump instead of the ordinary liquid pump will save the wear of the lime on the pump. In spraying with this wash clothing is ruined, and only the oldest garments should be worn. Care should be taken also to protect the eyes to avoid unnecessary inflammation.

THE SOAP TREATMENT.

Whale-oil or fish-oil soap, preferably made with potash lye, is dissolved in water by boiling at the rate of 2 pounds of soap to the gallon of water. If applied hot and on a comparatively warm day in winter, it can be easily put on trees with an ordinary spray pump. On a very cold day, or with a cold solution, the mixture will clog the pump, and difficulty will be experienced in getting it on the trees. Trees should be thoroly coated with this soap wash. Pear trees and apple trees may be sprayed at any time during the winter. Peach trees and plum trees are best sprayed in the spring, shortly before the buds swell.

If sprayed in midwinter or earlier, the soap solution seems to prevent the development of the fruit buds, and a loss of fruit for one year is apt to be experienced, the trees leafing out and growing, however, perhaps more vigorously on this account. The soap treatment is perfectly safe for all kinds of trees and is very effective against the scale. With large trees or badly infested trees, preliminary to treatment it is desirable, with this as well as other applications, to prune them back very rigorously. This results in an economy of spray and makes much more thoro and effective work possible. The soap can be secured in large quantities at from 3½ cents to 4 cents a pound, making the mixture cost, as applied to the trees, from 7 cents to 8 cents a gallon. The success of the soap treatment is largely influenced by the quality of the soap used. Many brands are on the market, mostly made with soda lye. A potash soap should be insisted on, and one that does not contain more than 30 per cent of water. The soda soap washes are apt to be gelatinous when cold and difficult or impossible to spray except when kept at a very high temperature.

KEROSENE TREATMENT.

This consists in spraying the trees with ordinary illuminating oil (coal oil or kerosene). The application is made at any time during the winter, preferably in the latter part, and by means of a spray pump making a fine mist spray. The application should be made with the greatest care, merely enough spray being put on the plant to moisten the trunk and branches without causing the oil to flow down the trunk and collect about the base. With the use of this substance it must be constantly borne in mind that careless or excessive application of the oil will be very apt to kill the treated plant. The application should be made on a bright, dry day, so that the oil will evaporate as quickly as possible. On a moist, cloudy day the evaporation is slow, and injury to the plant is more apt to result. If the kerosene treatment be adopted, therefore, it must be with a full appreciation of the fact that the death of the tree may follow. This oil has been used, however, a great many times and very extensively without consequent injury of any kind. On the other hand, its careless use has frequently killed valuable trees. Its advantages are its effectiveness, its availability, and its cheapness, kerosene spreading very rapidly and much less of it being required to wet the tree than of a soap and water spray. Pure kerosene is more apt to be injurious to peach and plum than to pear and apple trees, and the treatment of the former, as with the soap wash, should be deferred until spring, just before the buds swell. With young trees especially it is well to mound up about the trunk a few inches of earth to catch the overflow of oil, removing the oil-soaked earth immediately after treatment.

THE CRUDE-PETROLEUM TREATMENT.

Crude petroleum is used in exactly the same way as is the common illuminating oil referred to above. Its advantage over kerosene is that, as it contains a very large percentage of the heavy oils, it does not penetrate the bark so readily, and, on the other hand, only the light oils evaporate, leaving a coating of the heavy oils on the bark, which remains in evidence for months and prevents any young scale which may come from the chance individuals that were not reached by the spray from getting a foothold. Crude petroleum comes in a great many different forms, depending upon the locality, the grade successfully experimented with in the work of this Bureau showing 43° Baumé. Crude oil showing a lower Baumé than 43° is unsafe, and more than 45° is unnecessarily high. The lower specific gravity indicated (43°) is substantially that of the refined product, the removal of the lighter oils in refining practically offsetting the removal of the paraffin and vaseline. The same cautions and warnings apply to the crude as to the refined oil.

THE OIL-WATER TREATMENT.

Various pump manufacturers have now placed on the market spraying machines which mechanically mix kerosene or crude petroleum with water in the act of spraying. The attempt is to regulate the proportion of kerosene so that any desired percentage of oil can be thrown out with the water and be broken up by the nozzle into a sort of emulsion. Some of these machines, when everything is in good working order, give fairly satisfactory results, but absolute reliability is far from assured.

The best outlook for good apparatus of this sort seems to be in carrying the oil and water in separate lines of hose to the nozzle, uniting them in the latter, and in maintaining an absolute equality of pressure on both the oil and the water tanks by employing compressed air as the motive force, kept up by an air pump, the air chamber communicating with both of the liquid receptacles. Any other source of constant pressure, as carbonic acid gas or steam, will answer. One or more manufacturers are now working on apparatus of this general description. A 10-per-cent strength kerosene can be used for a summer spray on trees where the San Jose scale is multiplying rapidly and where it is not desirable to let it go unchecked until the time for the winter treatment. The winter treatment with the water-kerosene sprays may be made at a strength of 20 per cent of the oil. Applications of the oil-water spray should be attended with the same precautions as with the pure oil, and there is even somewhat greater risk, owing to the natural tendency one has to apply the dilute mixture much more freely than the pure oil. The application should be merely

enough to wet the bark, and should not, to any extent, at least, run down the trunk. The collection of water and oil about the trunk is just as dangerous to the tree as is that of the pure oil.

In the use of the oil sprays noted above one who has not had experience with them is advised to make some careful preliminary tests to fully master the process, preferably waiting two or three weeks to determine the results before entering on the general treatment of the orchard. It is well, also, with the oil-water mixtures, to test the pump from time to time, spraying into a glass jar or bottle to determine by actual measurement whether the correct percentages of oil and water are being maintained.

PETROLEUM-SOAP EMULSIONS.

The kerosene-soap emulsion, following chiefly the Riley-Hubbard formula, has been one of the standard means against scale insects for twenty years. The distillate emulsion generally employed in California for spraying citrus trees, on which the lime, sulfur, and salt wash can not be used, is substantially the same thing, except that it is made with the California distillate or petroleum oil. Crude petroleum of any kind, as well as the refined product, may also be used in making this emulsion. The use of the soap emulsions against the San Jose scale in the East has not been very general, on account of the greater facility with which the pure oil or oil-water mixtures can be applied. The difficulty of obtaining uniform results with the latter has led to a return to the use of emulsions to some extent, and there can be no doubt about their superior merit when it is desired to dilute the pure oils. Emulsions may be applied at any strength with absolute confidence that there will be no variation. Where the emulsion can be prepared wholesale by steam power its employment is attended with no difficulties. In California it is prepared by oil companies and sold at very slightly more than the cost of the oil and soap ingredients. It is made after the following formula:

Petroleum	gallons	2
Whale-oil soap (or 1 quart soft soap)	pound	½
Water (soft)	gallon	1

The soap, first finely divided, is dissolved in the water by boiling and immediately added boiling hot, away from the fire, to the oil. The whole mixture is then agitated violently while hot by being pumped back upon itself with a force pump and direct-discharge nozzle throwing a strong stream, preferably one-eighth inch in diameter. After from three to five minutes' pumping the emulsion should be perfect, and the mixture will have increased from one-third to one-half in bulk and assumed the consistency of cream. Well made, the emulsion will keep indefinitely and should be diluted only as wanted for use.

In limestone regions, or where the water is very hard, some of the soap will combine with the lime or magnesia in the water, and more or less of the oil will be freed, especially when the emulsion is diluted. Before use such water should be broken with lye, or rain water should be employed.

For winter sprays dilute the emulsion with either 3, 4, or 5 parts of water, giving a percentage of oil of approximately 17, 13, and 11 per cent. The strength in oil of this application on trees as compared with the oil-water sprays is the equivalent of 25, 20, and 15 per cent oil, because relatively more of the heavier oil-soap emulsion is held by the bark. The two stronger mixtures may be used on the apple and pear and the weaker one on peach and plum.

For summer applications dilute with 7, 10, or 15 parts of water, giving approximately 8, 6, and 4 per cent of oil. The weaker strengths may be used on trees with tender foliage, such as that of peach, and the greater strength for strong foliage plants, like the apple and pear.

FUMIGATION OF NURSERY STOCK.

All nursery stock which is under the least suspicion of contamination with the San Jose scale should be fumigated; and it is perhaps worth while to fumigate in any case to give the utmost assurance of safety to the purchaser. The hydrocyanic-acid-gas fumigation is the one to use. This gas is generated by combining potassium cyanide, sulfuric acid, and water. The proportions of the chemicals are as follows: Refined potassium cyanide (98 per cent), 1 ounce; commercial sulfuric acid, 1 ounce; water, 3 fluid ounces—to every 100 cubic feet of space in the fumigating room or house. The latter should be as nearly air-tight as possible and provided with means of ventilation above and at the side, operated from without, so that at the end of the treatment the poisonous gases can be allowed to escape without the necessity of anyone entering the chamber. The generator of the gas may be any glazed earthenware vessel of 1 or 2 gallons capacity, and should be placed on the floor of the fumigating room and the water and acid necessary to generate the gas added to it. The cyanide should be added last, preferably in lumps the size of a walnut. Promptly after adding the cyanide the room should be vacated and the door made fast. The treatment should continue forty minutes. It must be borne in mind that the gas is extremely poisonous and must under no circumstances be inhaled. The gas treatment is effective against the scale on growing trees in the orchard also; but the difficulty and expense of the treatment, except for nursery stock, make it prohibitive in the case of deciduous fruits.

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LEGISLATION AGAINST THE SAN JOSE SCALE.

As indicated in another place, no insect has been the subject of so much domestic and foreign legislation as has the San Jose scale. In this country nearly all the States have past laws regulating the sale and shipment of nursery stock and providing for inspection on account of this scale insect, and a great many foreign countries have made regulations regarding the importation of American plants and fruits.

The domestic legislation on insect matters, including the San Jose scale, was compiled by Doctor Howard and published as Bulletin No. 13 (new series) of this Office in 1898, and the foreign legislation up to 1900 is summarized by Doctor Howard in Circular No. 41 of this Office, published in August, 1900. There has been a great deal of additional legislation by different States subsequent to the publication of Bulletin No. 13, and by a resolution of the Association of Economic Entomologists and the American Association of Horticultural Inspectors this Office has collected, by the aid of special committees appointed by the two associations mentioned, all of the laws in their present form, and these have very recently been published as Bulletin No. 61 of the Bureau of Entomology. There have been also some charges in foreign legislation, and ultimately a revision of Circular 41 will be issued. The subject is much too large and bulky to be considered in this bulletin.

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